BBC WHY LIFE ON EARTH WASN'T AN ACCIDENT





What China's pioneering lunar mission means for the future of space exploration

BAD CAREERS ADVICE

Is it putting young women off working in science?

MIND BLIND

Inside the condition that leaves you with no imagination

THE END OF ACCENTS

How modern life is changing the way we speak











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Marmite can ease anxiety → p86

WELCOME



China has made the Moon exciting again. At the start of the year, the country's space agency dropped a lander and rover on the far side of the Moon, a place we've photographed but never visited. Named Chang'e 4, the mission is up there now studying the geology of the Moon's surface. It's even doing a bit of astronomy, from its uniquely quiet viewpoint. What it finds will help us understand the Moon's past: how it formed and why the far

side is so different from the bit we see. But perhaps more excitingly, Chang'e 4's roving could tell us what's in store for the Moon's future.

By digging into the Moon's geology, particularly on the far side, Chang'e 4 could spot vital resources. On the one hand, there are precious treasures up there that we need on Earth, like helium-3 (a useful fuel) and rare-earth metals. On the other hand, this geological intel can provide a clearer picture of what building materials are available for a future lunar mission. Similarly, data gathered on the amount of radiation experienced on the Moon will help shape the manned lunar missions that China hopes to launch in the next decade. That's just scratching the surface, though, as the mission is dripping with promise. To find out what Chang'e 4 has in store for us, and how it might stoke a new generation of space exploration, head over to p42.

And finally, next month our magazine is getting a refresh. Don't worry, we'll still be the magazine you know and love, but we have taken this opportunity to listen to your feedback and make some of the changes you've been asking for. For more details, turn to p97 and make sure you pick up a new-look issue on 6 March (we're pretty excited about it!).

Daniel Bennett

Daniel Bennett, Editor

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LUCY MADDOX

It turns out that some people cannot visualise anything in their mind's eye. Psychologist Lucy delves into this unusual condition. → p62



ANDY RIDGWAY

Social media and smartphone apps are revealing how our accents and dialects are changing. Science writer Andy finds out more. → p58



HELEN SCALES

Adam Summers is on a mission to image every fish in the sea using a CT scanner. Marine biologist Helen takes a look at these fish 'n' pics. → p52

WHAT WE'VE FOUND OUT THIS MONTH



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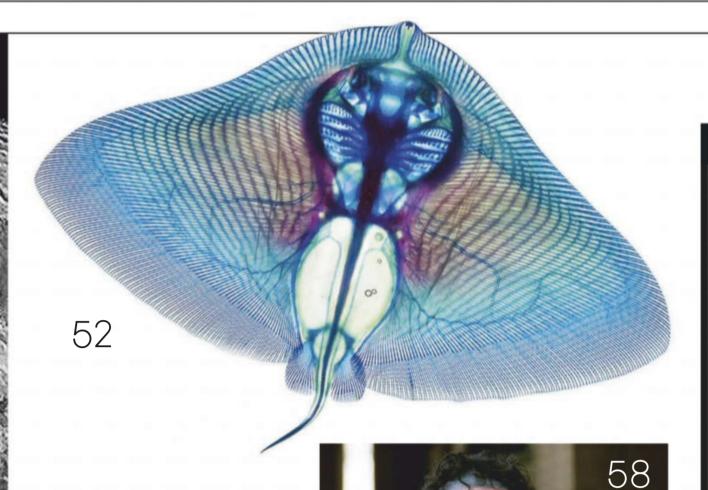
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FEATURES

A new race to the Moon

China's Chang'e 4 lunar mission has landed. Could this be the start of a new space race?

Gotta scan 'em all

Adam Summers is on a mission to image every fish in the sea... using a CT scanner.

Are accents dying out?

Eh up, chaps. The way we speak is changing, and new research can help us find out why.

Mind blind

We find out about aphantasia, a condition where you cannot 'see' things in your mind.

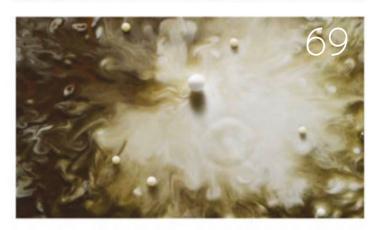
A new theory of life

Move over, biology, it's physics' turn to enjoy the spotlight.

Is bad careers advice putting girls off science?

We did some research to pinpoint what's turning girls off studying STEM.







WANT MORE?

Don't forget that *BBC Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.



Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. **sciencefocus.com**



SPECIAL ISSUE



THE SCIENTIFIC GUIDE TO A HEALTHY BODY & BRAIN

Health – either physical or mental – is a concern for all of us. This special edition, from the *BBC Focus* team, delves into the guidelines that will help you enjoy a happy, healthy 2019. buysubscriptions.com/focuscollection









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MESSAGE OF THE MONTH

WANTED: Schrödinger's cat - dead and alive

I wonder if Erwin Schrödinger had any idea that his use of the dead/alive cat thought experiment would echo down the decades as it has done.

Quantum mechanics is not an easy ride for professional physicists, let alone the rest of us, but Brian Clegg did a really good job in his article in the January issue of explaining this most counterintuitive of subjects. He set out the difficult ideas on entanglement and superposition by supporting them with experimental evidence.

The thing I'm interested to find out is did Schrödinger really believe in the possibility of superposition, or was he using the somewhat ridiculous cat idea because of his aversion to the notion itself. Perhaps there is another reason, which is rooted in his competition and desire to cast doubt on the Copenhagen Interpretation of quantum theory put forward by Niels Bohr and Werner Heisenberg. Alan Hudson, Grantham

Schrödinger was indeed opposed to the Copenhagen Interpretation of quantum mechanics, which states that an object in a physical system can simultaneously exist in all possible states until an observation forces it to collapse into just one of those states. He came up with his famous cat thought experiment to point out how ridiculous this ideas was. Of course, he thought, it is impossible for an animal to be both alive and dead at the same time. But many scientists disagreed with him and the debate as to what exactly is going on the quantum realm continues to rage.

- Jason Goodyer, commissioning editor

Quantum mechanics: one minute it's cats and contingent mortality, the next it's multiverses

Leeks: good in soups,

pies and bakes

Gravity over time

featured the question 'why does time seem to go faster as we get older?' Further to the answer you printed, I've always understood that it's because everything tends to go faster when you're going downhill!

In the January edition's Q&A, you

Ian Hutt, Little Chalfont, Bucks

Better food from better sources

Michael Mosley's approach to going vegan [as described in his column in the January issue] depends upon science and a larder of

ingredients from around the world – something that's only recently become possible. But

humans have evolved to be omnivores. Here in Wales much of the country can only grow grass, so we use sheep to eat the grass and then eat the sheep. It's what humans have evolved to do.

I suggest that the debate over food should not be about what we

eat so much as about the quality of what we eat. There is a huge

difference between, say, Welsh mutton or venison and factory-farmed pork or chicken. Even though I live in a town, it's relatively easy for me to purchase local, organically and

compassionately grown meat, fruit and veg. It's a healthy, sustainable and logical way to get

WRITE IN AND WIN!

The writer of next issue's Message Of the Month wins an STK X2, the most advanced device to date from the British mobile manufacturer. Running on Android 8.1 Oreo with a super-fast processor, the X2 is jam-packed with features to take on the big guns. Expect fingerprint technology and an outstanding 16MP camera. **stklife.com**



my food. Why do anything else? Simon Bartlett, via email

How old?

In January's Q&A on p86, Dr Alastair Gunn says that the boundary of the observable Universe is 46 billion light-years away. If this is so, then why is the Universe only 13.8 billion years old? How did the light set off from a time that's older than the age of the Universe?

Mary Colwell, via email

This is a common misunderstanding concerning the figures for the size and age of the Universe. The answer is that the figure of 46 billion light-years is the distance to the edge of the observable Universe now, not the distance at the time the light from there was emitted. In the time since the light was emitted, the Universe has expanded and that light has thus had to travel further, and taken longer to arrive, than if the Universe were static. The details depend on the expansion rate of the Universe, its evolution with time and the relative amounts of matter, radiation and dark energy in the Universe. But, put together, this means that matter that emitted light approximately 13.8 billion years ago would now be at a distance of approximately 46 billion light-years.

- Dr Alastair Gunn

The clue's not in the title

I first came across *BBC Focus* in the GP's surgery and was surprised to find it was a science publication, not a magazine for Ford car enthusiasts.

The issue I was reading had an article on the bits and pieces of rubbish left behind by the astronauts who walked on the Moon. I was called in to see the GP and when I came out, the copy of BBC Focus I was reading had disappeared. Since that encounter I've subscribed to the magazine and look forward to reading about the various topics you cover in each issue.

That said, I think it may be worth considering a change of name to something that better explains what the magazine contains and makes it immediately clear that it's got nothing to do with Ford cars.

Olad to hear you like the mag, Peter. And thanks for subscribing! Incidentally, we've been thinking about rebranding the magazine for a while now and plans are in motion to do just that. As a subscriber, keep an eye out for the new-look Science Focus that will be coming through your letterbox in the next few weeks.

- Daniel Bennett, BBC Focus editor



Cars do feature in the

mag from time to

time, but we don't

particular model

fixate on any

FOCUS

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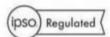
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The Royal Botanic Gardens, Kew is a charity exempt by law (under provisions of the Charities Act)

Image: Round-leaved sundew (Drosera rotundifolia)



DISCOVERIES DISPATCHES FROM THE CUTTING EDGE

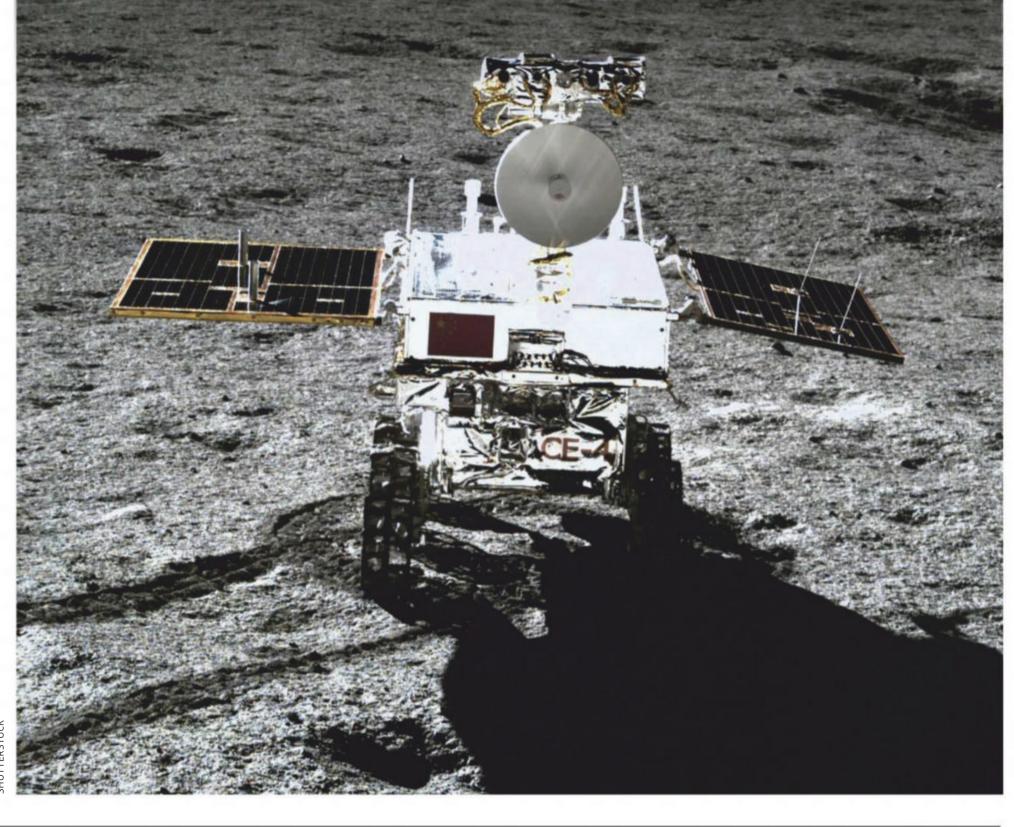
FEBRUARY 2019

EDITED BY JASON GOODYER

SPACE

FIRST PLANT GROWN ON THE MOON

A tiny cotton seed aboard China's Chang'e 4 probe became the first ever plant to sprout on the Moon, but was unable to make it through the freezing lunar night

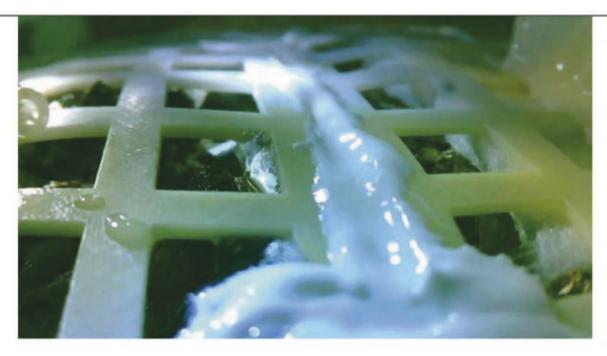


On 3 January China's Chang'e 4 became the first lunar probe to land on the far side of the Moon. Two weeks later, the probe achieved another first when it sent back a grainy photograph showing tiny green shoots sprouting from a cotton seed stored inside its Lunar Micro Ecosystem biosphere experiment.

The success was short-lived, however: on 16 January it was reported that the shoot had failed to survive the freezing temperature of the lunar night. None of the other organisms on board — potatoes, rapeseed, mouse-ear cress, yeast or fruit fly eggs — showed any signs of life and the experiment was called off just a few days into its planned 100-day stint.

Shortly after landing, the 3kg, 18cm biosphere was powered up, the internal temperature adjusted to 24°C and the seeds watered. Twelve days later, the Advanced Technology Research Institute at

"THE SUCCESS WAS SHORT-LIVED,
HOWEVER: ON 16 JANUARY IT
WAS REPORTED THAT THE SHOOT
HAD FAILED TO SURVIVE THE
FREEZING TEMPERATURES"



The second shot sent back from the Chang'e 4 probe showed the cotton shoot had perished in the cold lunar night

Chongqing University reported that the cotton seed had sprouted and released an image of the shoot. A second photo followed

24 hours later showing that the shoot had perished (above).

The successful harvesting of plants is seen as a vital part of any attempt to establish a permanent base on the Moon or even long-term expeditions, such as a manned mission to Mars.

China's next mission, Chang'e 5, which is scheduled for launch in December, will attempt to collect samples of lunar rock and soil from the surface of the Moon and return them to Earth. There are also whispers that the Chinese National Space Administration plans to build a space station near the Moon within the next decade.

For a full breakdown of the Chang'e 4 mission, turn to p42

OTHER PLANTS GROWN IN SPACE



Rock cress

Way back in 1982, the crew of the Soviet Salyut 6 space station successfully grew a small crop of rock cress using a Fiton 3 micro greenhouse. These were the first plants to flower and produce seeds in space.



Sunflower

Green fingered astronaut Don Pettit grew several different plants as part of his personal biology experiments during his time aboard the ISS in 2012. Among them was this sunflower.



Zinnia flowers

On 16 January 2016 Commander Scott Kelly shared photographs of a blooming zinnia flower grown using the Vegetable Production System (Veggie) on board the International Space Station.



Space salad

In October 2017 a group of astronauts led by astronaut Joe Acaba tucked into a salad made with mizuna mustard leaves, green lettuce and red romaine lettuce, again grown using the Veggie system.

EXPERT COMMENT

Lewis Dartnell

Prof Lewis Dartnell is an astrobiology researcher and author of Origins: How The Earth Made Us

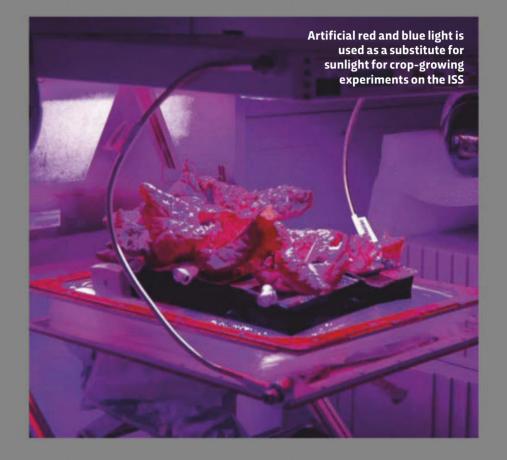
Although the Lunar Micro Ecosystem experiment ultimately did not run for as long as had been planned, it still represents a significant step forward in our attempts to provide for off world explorers. Like an automated, miniaturised version of Matt Damon's character in the film *The Martian*, this sealed biosphere was briefly able to grow plants on the surface of another world.

Previous space farming experiments have focused on two main approaches: either testing plant growth in the microgravity environment of the International Space Station (ISS), or Earth based experiments that involve investigating how well different crops develop in simulated lunar or Martian soils

The problem with the microgravity environment of spacecraft such as the ISS is that plant seeds need to sense the direction of gravity to know which way to send their roots and shoots. The ISS also has no onboard greenhouse to let in the natural sunlight, so these small scale farming experiments have to be conducted under artificial electric lighting: red and blue LEDs that give these experiments a lurid magenta glow.

Using the ISS's Vegetable Production System (Veggie), for example, astronauts have been able to successfully grow red romaine lettuce in space. The first crops successfully grown using the Veggie system appeared in 2014. The produce was harvested, frozen and taken back to Earth to be tested, but in 2015 the astronauts were able to actually eat the space salad they'd grown. And in 2016, US astronauts aboard the ISS posted photos of the zinnia flower they'd been nurturing. ISS astronauts are now moving on to try to grow other crops such as dwarf wheat.





Meanwhile, other experiments down on the ground have been trying to see if plants can be grown in soils like those present on the Moon or Mars. Previous space missions have measured the composition of the powdery regoliths of the lunar and Martian surface, and so these can be recreated as simulant soils in the lab. For example, in 2014 scientists at the Dutch Wageningen University and Research Center tested several wild weeds as well as crops in their ersatz extraterrestrial dirt. But the seedlings fared badly, if they had managed to germinate at all. The researchers realised that 'raw' lunar or Martian soil, made only of crumbled rocks, is very bad at holding water or providing essential nutrients. When they tried again with some organic matter mixed in, much more like the soil found in a garden on Earth, they achieved much better results. Ten species, including peas and tomatoes, yielded produce. One problem that's yet to be solved is that lunar and Martian regolith contain lots of heavy metals, and so plants grown in them and absorbing these elements through their roots could be too toxic to be eaten by astronauts.

But the Chang'e experiment is the first time that plant growth has ever been attempted on the surface of another world. And it was ground breaking for another reason, too. Most of the studies so far have focused on growing just a few plant types in isolation, but the Lunar Micro Ecosystem was attempting to establish a genuine synergy between the different species it kept alive. The plants growing to provide oxygen and food for the flies, these insects respiring to release carbon dioxide for the plants, and the yeast breaking down and recycling both when they died: a self contained mini ecosystem of primary producers, consumers and decomposers. It's this sort of 'closed' loop' ecological approach that is exactly what will be required for the long term human colonisation of space. At the moment, food is regularly resupplied to the space station by rocket launches, but this would be impossibly expensive to support long term human habitation on the Moon or Mars. In the future we will have to become space farmers, and the Chang'e experiment is an important step towards that.





ARTIFICIAL INTELLIGENCE USED TO DECODE RODENT CHITCHAT

Despite the popular saying, mice are rarely quiet they are highly social animals that are constantly communicating with one another via complex vocalisations. But their squeaks can be difficult to pick up as they frequently exceed the limits of human hearing and are so quiet that they can be difficult to separate from background noise.

Now, a team at the University of Washington that's investigating the effects of addictive drugs such as alcohol or opioids has developed a piece of software to listen in on the chitchat of rats and mice. Dubbed DeepSqueak, the program transforms audio signals into sonograms, visual representations of the sounds, that can be analysed using AI techniques, similar to those that enable driverless cars 'see' their environment. In this context, however, DeepSqueak is allowing researchers to separate the rodents' calls from background noise.

"The animals have a rich repertoire of calls, around 20 kinds," said Dr Kevin Coffey, a

postdoctoral fellow in the University's Neumaier lab. Coffey and his colleagues found that male rodents made happy sounds when they were anticipating a reward, such as sugar, or were playing with their male peers. But, when they sensed a female rodent nearby, their vocalisations became more complex, as if they were singing a courtship song. This effect became even more dramatic when they could smell but not see the female, suggesting that they have distinct songs for different stages of courtship.

Thanks to its low cost and convenience, it is hoped

"If scientists can understand better how drugs change brain activity to cause pleasure or unpleasant feelings, we could devise better treatments for addiction," said laboratory director Prof John Neumaier.

that the technique can eventually be used in the investigation of the effects of addictive drugs by monitoring the psychological states of rodents in various stages of withdrawal.

ASTRONOMY

BIRTH OF A BLACK HOLE WITNESSED FOR FIRST TIME

Last June, astronomers noticed the appearance of a mysterious bright object in the constellation of Hercules. It remained visible for a little over two weeks, during which time they dubbed it 'the Cow'. Now, scientists investigating the phenomenon believe that what astronomers witnessed was the formation of a black hole or a neutron star.

When stars burn off all their energy, they either explode in a nova or supernova, or collapse to form a white dwarf, a neutron star or a black hole, depending on their mass. When the Cow was spotted, astronomers thought the bright light must be coming from a supernova. But the Cow burned faster and brighter than any previously observed supernova, so a team led by Dr Raffaella Margutti of the Center for Interdisciplinary Exploration and Research in Astrophysics at

Northwestern University in Illinois decided to investigate further. "We know from theory that black holes and neutron stars form when a star dies, but we've never seen them right after they're born," said Margutti.

The researchers gathered data from several telescopes – the WM Keck Observatory in Hawaii, the MMT Observatory in Arizona, the SoAR Telescope in Chile, the Very Large Array in New Mexico, and the NuSTAR and XMM-Newton space observatories – to study various wavelengths of light coming from the Cow. By combining the views from each of these telescopes – and helped by the fact that there's little ejected material orbiting the Cow - the team were able to peer into the object to its central radiation source and conclude that it must be a newborn black hole or neutron star.





MIGRAINE SUFFERERS

A team at the University Hospital of Amiens-Picardie in France has found that regular Botox injections lessen the regularity of migraines by an average of 1.6 attacks per month in chronic sufferers.

TEENAGE TECHNOPHILES

Using smartphones, tablets and game consoles is no more harmful to youngsters' mental wellbeing than eating potatoes, researchers at the University of Oxford have found. A study of 300,000 teens showed that only 0.4 per cent of adult wellbeing is related to screen use.

GOOD MONTH

BAD MONTH

PEOPLE WHO LIVE IN FLATS

Living in a house with no shared walls may help protect you from heart disease, says a team at the University of Essex. A study of 10,000 people found those living in detached houses had half the levels of C-reactive protein – a chemical linked to angina, heart attacks and strokes – of those living in flats.

PIANISTS

Look out, Liberace! Engineers at the University of Cambridge have created a 3D-printed robot hand that's capable of playing the piano in different styles.



"We discovered the most distant object ever observed in our Solar System"

Astronomers led by Dr Scott Sheppard of the Carnegie Institution for Science have found 2018 VG18 – a new dwarf planet that's been nicknamed 'Farout'

ABOVE: Dwarf planets orbit a parent star and have sufficient gravity to form themselves into a roughly spherical shape

How did you spot dwarf planet 2018 VG18?

We've been doing the largest, deepest survey for distant Solar System objects. In the past we had big telescopes, but it was like looking through a straw at the sky – we could only cover very small areas at faint depths. But the digital cameras we're now using are as big as a small car, and they allow us to cover bigger areas. Five to six years ago, one image would be smaller than the field of a full Moon and now we're covering 10 times that.

In November 2018, we discovered the most distant object ever observed in our Solar System, which is at a distance of 120 astronomical units [one astronomical unit is the distance from the Earth to the Sun]. That's over 3.5 times further out than where Pluto is.

Why was it nicknamed 'Farout'?

We take two images, separated by a few hours to a day or two, and look for anything that moves. Stars and galaxies are far away, so they don't really move, but things in our Solar System are much closer. And the moment I saw this object – it's the slowest object I've ever seen moving – I uttered to myself "Farout!", which is like "that's cool!" So there's a double connotation to that word, because it's so far

away and it's a very cool object. If you're on Farout, the Sun would just be another star in the sky.

What do we know about its appearance?

It's kind of pink in colour, and this suggests that its surface is icy because if you expose ice to the Sun's radiation over billions of years, it turns pinkish. We know how far away Farout is and roughly how bright it is, so we can deduce how big it must be. We don't know exactly how much light it reflects, if it's as bright as snow or as dark as coal, but if we assume it's somewhere between the two, it's about 600km wide — a quarter of the size of Pluto.

The definition of dwarf planet is you have to be big enough where gravity will crush the material and make the object spherical. Farout is big enough. Right now we know of 30 or so dwarf planets – most are in the Kuiper Belt, the area just beyond Neptune. We're continuing our survey, we've covered about 20 per cent of the sky to a pretty faint level and so we hope to uncover more dwarf planets, if not a really big object like a 'Planet X'.

How could Farout help us find 'Planet X'?

Planet X is a planet that may or may not exist. We think it's more likely than not it exists, but it's



probably five to 10 times further out than Farout is. Planet X has to be massive, five to 10 times larger than Earth. Gravitationally, it should dominate the outer Solar System region, and Farout is so far out that Planet X should be pushing Farout around. Farout's orbit probably takes more than 1,000 years to go around the Sun: we'll need to observe for

> another year or two to get enough motion of its arc to determine its full orbit.

Where did Farout come from?

That's the big unknown. It could have an elongated orbit that brings it into the inner Solar System – if that's true, it interacted with one of the giant planets and got thrown outwards. But if its orbit never brings it any closer, then it's hard to explain, because the amount of material that far out is probably not enough to form large objects like this.

THEY DID WHAT?!



RESEARCHERS GET FRUIT FLIES DRUNK

What did they do?

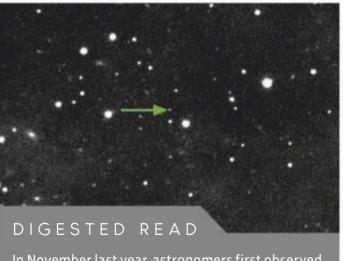
A team at Scripps Research Institute fed fruit flies liquid food laced with alcohol and observed the effects of the ethanol on nerve cells in their brains.

What did they find?

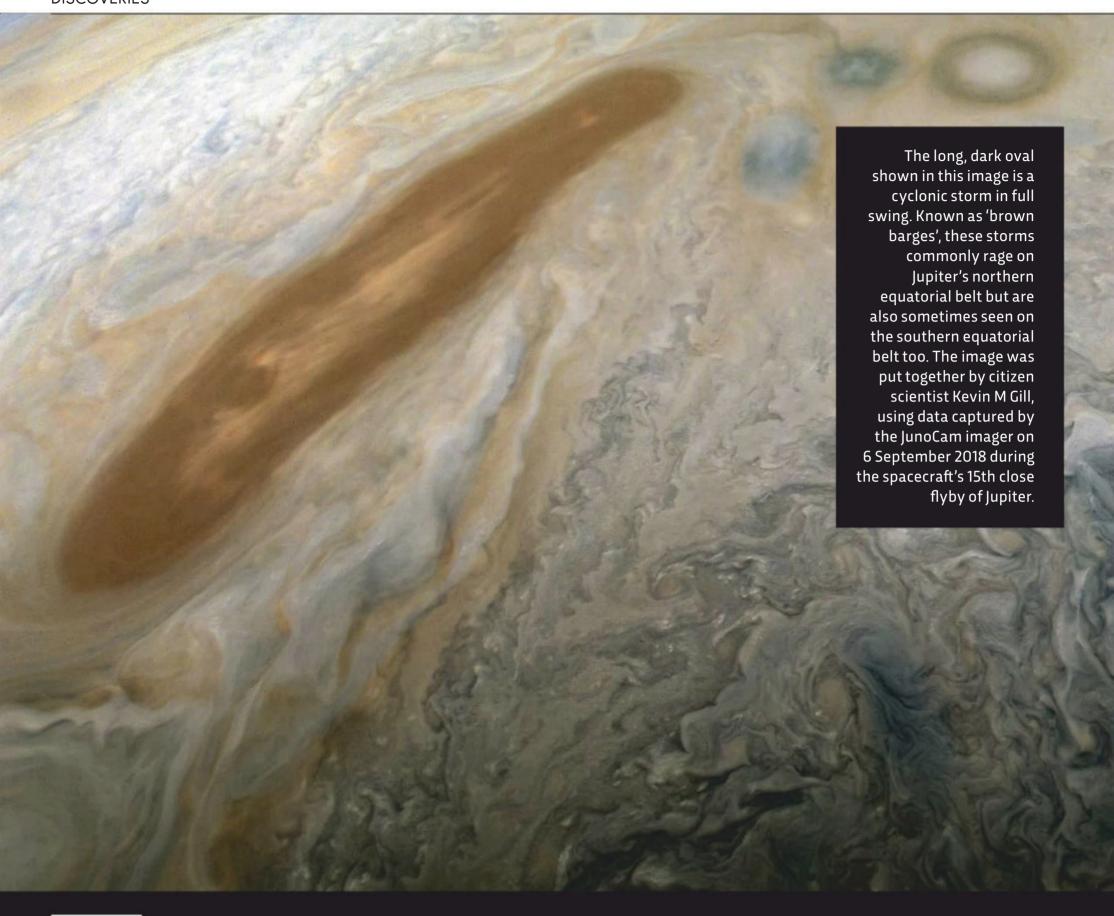
Much like people who enjoy a tipple, flies that drink alcohol begin losing their coordination before becoming hyperactive. They found that an enzyme called phospholipase D2, which plays a role in anaesthesia, built up in the flies' nerve cells. This caused the nerve cells to fire more easily, resulting in hyperactive flies.

Why did they do that?

The study is the first time that the direct action of D2 on nerve cells has been linked to the consumption of alcohol. Further study of the effect could lead to treatments designed to prevent us from getting intoxicated or even from suffering from hangovers, the researchers say.



In November last year, astronomers first observed the dwarf planet 2018 VG18, nicknamed 'Farout'. It's the most distant object ever observed in our Solar System. By studying its orbit, astronomers could determine whether or not the hypothetical Planet X exists.



SPACE

NASA'S JUNO PROBE HITS THE HALFWAY MARK

Since its launch more than seven years ago, NASA's Juno space probe has completed 16 close flybys of Jupiter. Throughout its journey, the probe's JunoCam has delivered some of the most spectacular images of the giant planet ever, detailing the swirls of its atmosphere in unprecedented detail.

"While originally envisioned solely as an outreach instrument to help tell the Juno story, JunoCam has become much more than that," said Dr Candice Hansen, Juno co-investigator at the Planetary Science Institute in Tucson, Arizona. "Our timelapse sequences of images over the poles allow us to study the dynamics of Jupiter's unique circumpolar cyclones and to image high-altitude hazes. We are also using JunoCam to study the structure of the Great Red Spot and its interaction with its surroundings."

As the mission is now at its halfway point, we've selected some of its most breathtaking shots.



This stunning image of Jupiter's tumultuous cloudscape was pieced together by citizen scientists Gerald Eichstädt and Seán Doran using data from the spacecraft's JunoCam imager taken on 29 October 2018. It has been colour enhanced to show the complex patterns formed as the storms rage in the planet's atmosphere.



This timelapse image was taken over 40 minutes on 1 April 2018 as the spacecraft performed its 12th close flyby of Jupiter. It shows a southern tropical disturbance stealing threads of orange haze from Jupiter's iconic Great Red Spot. It was created by citizen scientists Gerald Eichstädt and Seán Doran using data from the spacecraft's JunoCam imager.



9 JUNE 2005

Juno is selected as the second mission to be funded under NASA's New Frontiers project, following the New Horizons mission. NASA had previously rejected two other proposed missions, INSIDE Jupiter and the Europa Orbiter.

5 AUGUST 2011

Juno launches from Cape Canaveral, on board an Atlas V rocket. The probe carries nine scientific instruments, including the JunoCam camera, and tools for studying the planet's composition, gravity, magnetic field and polar magnetosphere.

OCTOBER 2013

Juno carries out a flyby of Earth. This enables scientists to test out its instruments, and takes advantage of Earth's gravity to slingshot the craft towards Jupiter. Such a manoeuvre in spaceflight is known as a 'gravity assist'.

5 JULY 2016

Juno goes into orbit around Jupiter. Its orbit is elliptical: at perijove – the closest point in its orbit to Jupiter itself – it comes within some 4,200km of the planet; at apojove – the furthest point – it is some 8.1 million kilometres away. Each orbit takes 53 days.

27 AUGUST 2016

Juno reaches perijove for the first time. JunoCam sends back its first grainy images of the planet's north and south poles, while the Jovian Infrared Auroral Mapper provides an infrared image of Jupiter's southern aurora.

11 JULY 2017

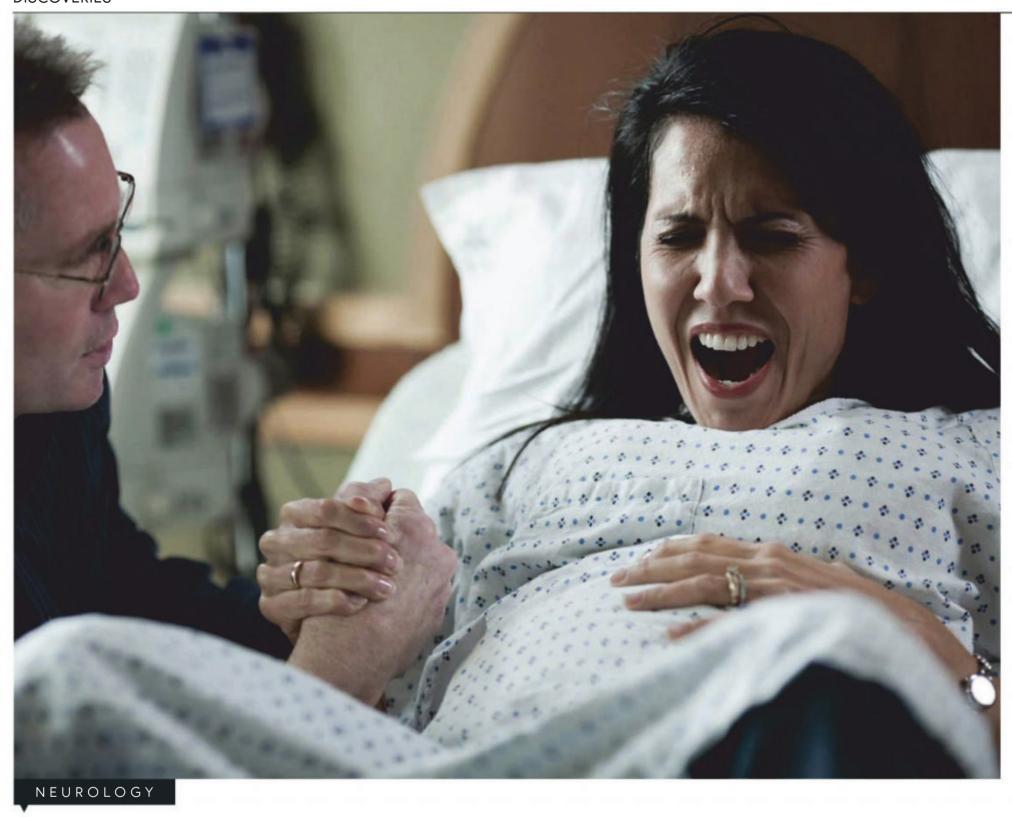
Juno flies over Jupiter's Great Red Spot. As a result, scientists learn that the storm extends deeper into the atmosphere than was previously thought – it's now believed to be 50-100 times deeper than the oceans here on Earth.

21 DECEMBER 2018

Juno carries out its 16th pass of Jupiter, making the halfway point in the craft's fact-finding mission. It has now provided low-resolution images of the planet's entire surface; the second half of the mission will double the resolution of these images.

30 JULY 2021

The date when Juno will be deliberately deorbited into the Jovian atmosphere, where it will burn up. The descent will be carefully controlled, to avoid surrounding Jupiter with a ring of space junk.



WOMEN 'FORGET' PAIN MORE EASILY THAN MEN

Men and women seem to remember pain differently, according to new research from McGill University in Montreal, Canada. When feeling a pain for the second time, men feel the sensation more strongly – but women don't. This link between pain and memory could hold the key to the treatment of chronic pain.

The researchers inflicted mild pain on human and mouse subjects by applying heat to their skin, followed by more intense pain – for humans, exercising their arms while wearing a tight blood pressure cuff for 20 minutes, and for the mice, a temporary stomach ache induced by an injection of vinegar. The following day, the subjects then experienced the milder, heat-based pain again. The reactions to the pain stimuli were then studied. The male humans and mice appeared to react more strongly to the second milder pain, while the female subjects reacted the same way to both.

The team think that the anticipation of potentially experiencing a repeat of the more intense pain made the male

participants more stressed, which in turn made them more sensitive to the second milder pain.

Dr Jeffrey Mogil, lead author of the study, suggested two possible reasons for this disparity: "One is that the women aren't remembering the pain. The other is that the women are remembering the pain just fine, and they're just not getting stressed by it. Although women are clearly more sensitive to pain than men, they also clearly have more experience with it," explained Mogil. "Menstrual pain, recurring abdominal pain and headaches are far more common in teenage girls than boys."

The researchers found that by blocking the memory of the pain in the mice by administering the drug zeta inhibitory peptide, the males' increased response was entirely removed. "The implications are that, instead of attacking the pain directly in chronic pain patients, you could try to attack the memory of the pain," Mogil said.

Your guide to the hottest topics in the world right now

#OBESITY



LATEST UK OBESITY FIGURES

The NHS's latest figures on obesity, taken from 2017 data, reveal that 27 per cent of men, 30 per cent of women, and 16.5 per cent of children aged between 2 and 15 are classified as obese. This is a small increase from previous years. New measures that have been suggested to combat childhood obesity include *Pokémon*-like interactive augmented-reality games, a ban on confectionery adverts before 9pm and restrictions on two-for-one deals in shops.

OBESITY ALONE MAY NOT INCREASE RISK OF DEATH

A study of almost 55,000 people carried out by researchers at York University, Canada, has found patients with metabolically healthy obesity (a form of obesity in which someone may have a body mass index that's above 30 but not have any metabolic abnormalities such as high blood pressure, high cholesterol or diabetes) do not have an increased risk of mortality.

#AIR POLLUTION

BACTERIA THRIVE IN POLLUTED AIR
Chinese researchers have found that
Beijing's notorious smog – itself a
health hazard – also provides an ideal
breeding ground for airborne bacteria,
which feed on the various sulphate and
nitrate chemicals in the smog. Not only
does this increase local people's
exposure to disease, but both the
bacteria's faecal matter, and the
bacteria themselves if clumped
together, can also act as an additional,
hitherto unaccounted-for form of
particulate pollution.



MUCK-SPREADING POLLUTION TARGETED Animal manure is a source of ammonia, a potent chemical that can combine with other airborne pollutants to create particulate matter, which can be harmful if inhaled. Defra is putting measures in place to require slurry-spreading farmers to upgrade their equipment to reduce the amount of pollution by 2025.

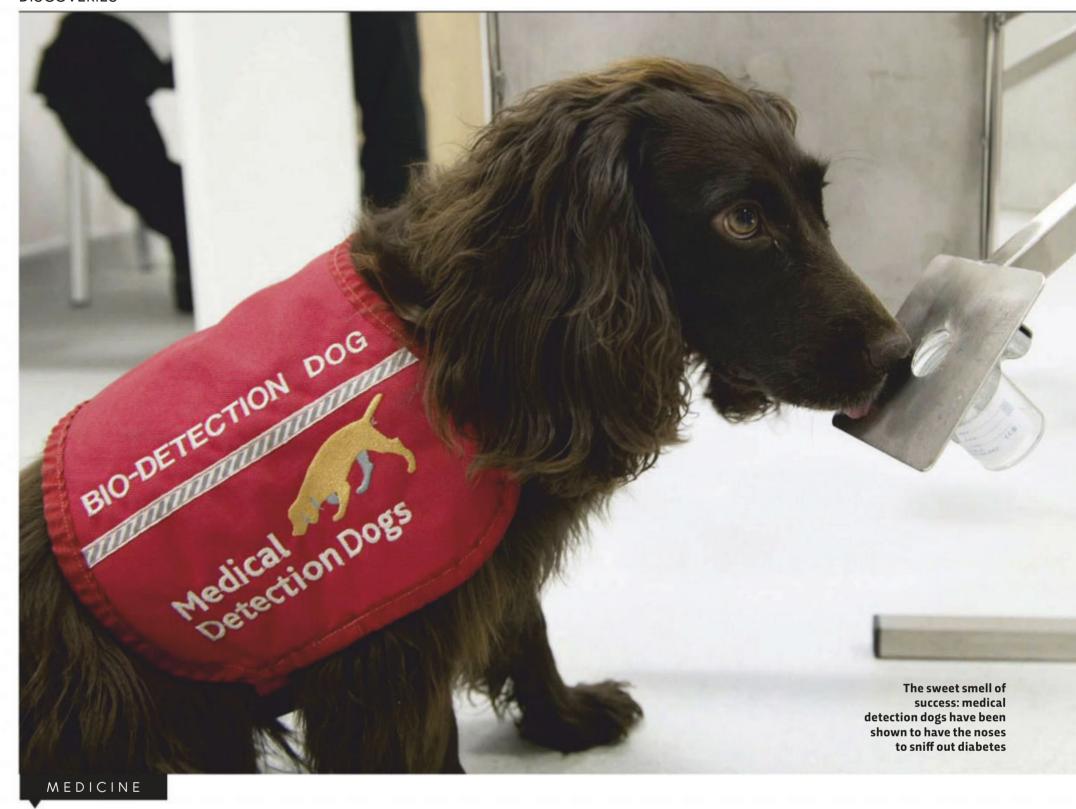
#CLIMATE CHANGE

WARMER OCEANS ARE CREATING STRONGER TIDES
Rising ocean temperatures driven by climate
change are leading to an increase in the energy
contained in waves, a study at the University of
California has found. Warming of the upper ocean
has influenced wind patterns globally, which is
making waves stronger.

ANTARCTIC ICE LOSS HAS INCREASED RAPIDLY OVER THE LAST FOUR DECADES

Another study carried out by the University of California has found that the melting of Antarctic icecaps has increased six-fold in the last 40 years, leading to a global sea level rise of around two centimetres. Average ice loss between 2009 and 2017 was 252 billion tonnes a year.





DOGS ARE A DIABETIC'S BEST FRIEND

As far back as the 16th Century, dogs were used as guides for blind people. Since then, they've come to play a much wider role in healthcare. Today, guide dogs have been joined by medical detection dogs that have been trained to sniff out cancer, along with various other medical conditions including type 1 diabetes, severe nut allergies and Addison's disease (a rare disorder of the adrenal glands), and soon possibly even Parkinson's disease and malaria as well.

Previous studies have found that medical detection dogs show promise in sniffing out disease but more rigorous proof has yet to be produced. Now, after the recent completion of the first large-scale study into the abilities of medical detection dogs, that's now changed – at least as far as dogs trained to sniff out type 1 diabetes are concerned. The study, carried out by the University of Bristol Veterinary School,

"MEDICAL
DETECTION
DOGS HAVE
BEEN TRAINED
TO SNIFF OUT
CANCER, TYPE
1 DIABETES AND
ADDISON'S
DISEASE"

took place over a period of six to 12 weeks and tracked the performance of 27 glycaemia alert dogs, which had been trained to detect when their owner's blood sugar level is too high (hyperglycaemia) or too low (hypoglycaemia). During that time the dogs' owners were asked to record every hypoglycaemic or hyperglycaemic episode they experienced. After analysing the results, the researchers found that the dogs had alerted their owners to 83 per cent of hypoglycaemic episodes, and 67 per cent of hyperglycaemic episodes.

"We already know that a patient's quality of life is vastly improved by having a medical detection dog," said Dr Nicola Rooney, who led the research. "But to date, evidence has come from small-scale studies. Our study provides the first large-scale evaluation of using medical detection dogs to detect hypoglycaemia."

SHUTTERSTOCK, NASA

THINGS WE LEARNT THIS MONTH

HUMANS HAVE 35 COMMON FACIAL EXPRESSIONS

There are just 35 facial expressions that are commonly understood across almost all cultures – 17 of which express happiness, while just one suffices for disgust.
Cognitive scientists at Ohio State University typed over 800 words that describe feelings, in five languages, into the most popular search engines on five continents, and analysed the 7.2 million resulting images.

TERMITES BENEFIT RAINFORESTS

Here's something to chew on: termites protect tropical rainforests from drought, a new study in Hong Kong has discovered. The presence of termites speeds up the process of leaf litter decomposition, leading to soils that are moister and richer in nutrients during dry spells.

OFFICIAL: GM OPPONENTS LACK UNDERSTANDING

Studies in the US, France and Germany last year found that the people who most strongly oppose GM crops have the poorest scientific understanding – yet rate their own knowledge the highest. Those who performed best in tests of basic scientific knowledge were the least likely to object to GM crops.

ASTRONOMY

HUBBLE SPIES ON THE NEIGHBOURS

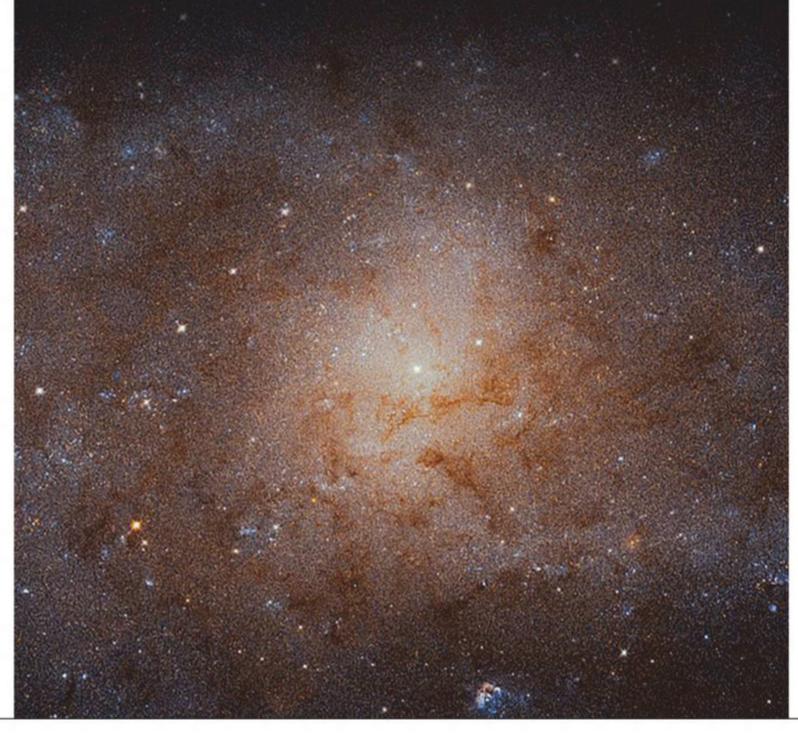
This image of Messier 33, one of our nearest galactic neighbours, was snapped by the Hubble Space Telescope during a panoramic survey. Also known as the Triangulum Galaxy, Messier 33 is one of the most distant objects that's visible with the naked eye (in favourable conditions). It's also one of the three large galaxies in our Local Group, the other two being our own Milky Way and the Andromeda Galaxy. Like the Milky Way and Andromeda, it's a spiral galaxy, though it lacks a central bulge, and is much smaller, at 60,000 light-years across (compared to 100,000 for Andromeda and 200,000 for the Milky Way).

The Triangulum Galaxy is a hotbed for star formation, with a new solar mass star forming within it roughly every two years. It

was this constant star-formation activity that inspired the Hubble team to image the galaxy in as much detail as was possible.

The end result is an image measuring 34,372 by 19,345 pixels – that's a staggering 665 million pixels, second in size only to Hubble's 2016 image of the Andromeda Galaxy. Within the image, around 10 to 15 million individual stars can be discerned, though even that is just a small fraction of the 40 billion or so stars believed to make up Messier 33.

It is hoped that the new image, combined with existing images of the Milky Way, the Andromeda Galaxy and the Large Magellanic Cloud, will help astronomers improve their understanding of how stars form and how they evolve over time.



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PREDICTIVE SYSTEMS ARE BIASED





Aleks Krotoski is a social psychologist, broadcaster and journalist. She presents BBC Radio 4's *Digital Human*.

here is an old idea in the Highlands of Scotland that the 12, 13 and 14 of February are 'borrowed' from January. At this point in the year, it feels like it's going to be dark and wet forever. And so, to preserve their mental health and to predict how to approach the growing season, the Highlanders looked to what they could see, touch, smell and feel, and made up a story that would give them a vision into the future. The more miserable those days were, the better the weather would be for the rest of the year. If it was nice, though, it would be pishing it doon 'til spring.

This old wives' tale gave the people living in cold darkness the impression that they had some control over their unpredictable lives. This is important, because humans don't like randomness much. Thousands of businesses have grown out of this desire to alleviate our discomfort, with technologists being the latest oracle in a roster of market analysts, trend forecasters and fortune tellers. Artificially intelligent systems predict what we want to say or buy or do. I don't even need to use my brain to respond to an email. I just jab my monkey finger at one of three autoreply options – 'Sure thing!' 'No thanks!' 'How about next Saturday?' – and the machine does the rest.

Like all prognosticators, it isn't foolproof. Sometimes those predictive texts are hilarious, and sometimes they reveal a little of the Universe's inner workings. Take, for example, Mauritania. This African country is right smack in the middle of warring nations, but has managed to remain independent. It is, however, so "publicly unrecognisable" – according to an article published in *Perceptions* in 2017 – that 'Mauritania' is replaced by the word 'Martian' when it's typed into a smartphone. Awkward. And embarrassing. Despite the crucial diplomatic role this country plays, the Universe according to predictive text says it's unimportant.

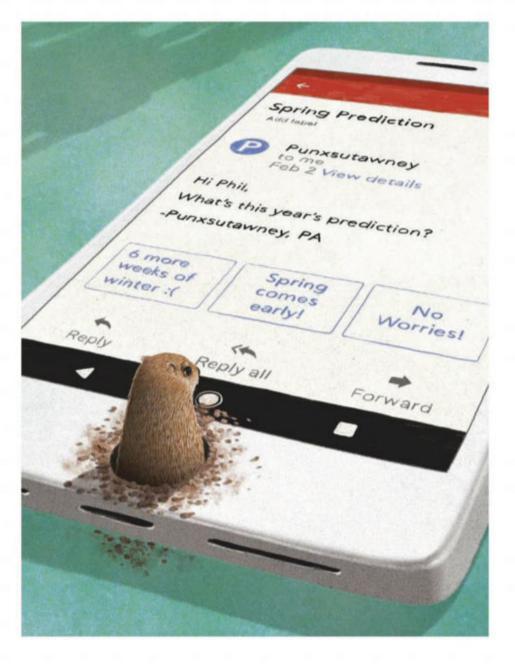
I'm going to return to the weather now, as I'm British.

"I JUST JAB MY MONKEY FINGER AT ONE OF THREE AUTO-REPLY OPTIONS" I adore the Bill Murray film *Groundhog Day*. The story plays out on 2 February, the US's version of the Highlanders' borrowed days. Every year, a groundhog looks for its shadow, and weather predictions can be made from that. Yes, exactly as baseless.

Murray plays a cynical weather man who must make his annual pilgrimage to Punxsutawney, Pennsylvania to watch 'Phil' the groundhog predict the weather. He despises the town, the job, and most of all, Phil. The Universe, in its infinite and random wisdom, decides that he is wrong, and must relive the same 2 February again and again until he learns to become a better person. And then time can move forward again.

An article in the journal *Screen Education* in 2017 argued that this innocuous romantic comedy is a useful entry point to think about altruism, happiness and existentialism. Indeed, the film tells viewers that treating people (and animals) well, and finding pure joy in classical music, French poetry, snowball fights and ice sculpting is the best way to live life and find love.

Meanwhile, predictive text tells me that my time is precious, politeness can be programmed and Martians are more important than Mauritania. And the most important thing to remember is that each of the predictive systems we put our faiths in – the market analyst, the trend forecaster, the fortune teller, autocorrect or rodent – promote a reality based on the implicit biases of an invisible deity, so we should take care when listening to their advice. •



IS DAILY FASTING THE NEW 5:2?



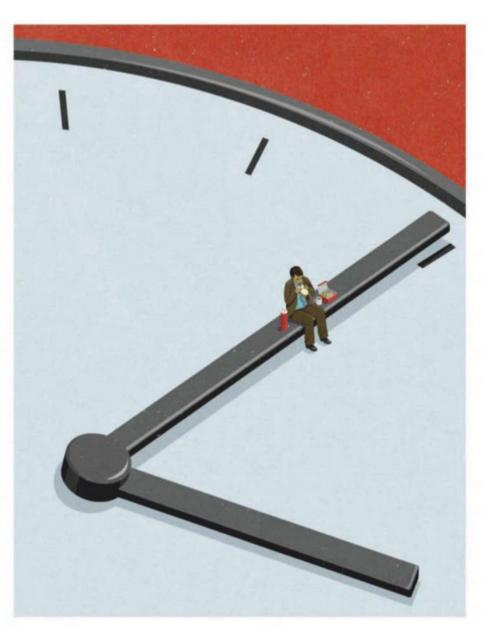
TWO

Michael Mosley is a science writer and broadcaster. His new book, *The Fast 800*, is out now (£8.99, Short Books). You can also book tickets for his first UK wide tour, running through February and March, at michaelmosley.co.uk

even years ago I discovered, thanks to a chance blood test, that I was a type 2 diabetic. Rather than start on medication, I wanted to see if there was another way to reverse my diabetes. So I made a Horizon documentary called Eat, Fast, And Live Longer during which I discovered the joys of intermittent fasting. The idea behind this approach is that you can lose weight and improve your health by significantly cutting your calories a few days a week, or by going for longer periods than you normally would without eating. A popular form of intermittent fasting is the 5:2 approach. This involves cutting your intake to around 600 calories a day for two days a week, then eating healthily for the other five. Using 5:2, I lost nine kilograms and returned my blood sugar levels to normal. Others have done likewise. A recent controlled trial of type 2 diabetics doing the 5:2, published in the journal JAMA, found average weight loss of around seven kilograms, sustained for over a year.

But there's another form of intermittent fasting, called Time-Restricted Eating (TRE), which has recently taken off. The rules of TRE are simple: you try to eat most of your calories within a small time window, such as eight hours. Once you have decided your time window (perhaps 11am to 7pm) you don't eat or drink anything that contains calories outside of that time window. The person who pioneered TRE is Dr Satchin Panda at the Salk Institute in San Diego, one of the world's leading research centres for biomedicine and life sciences. In 2012 he and his colleagues published a study in the journal *Cell Metabolism*, where they took two groups of mice and fed them a high-fat, high-sugar diet. All the mice got exactly the same amount of food, the only difference being that the mice in group A were allowed to eat whenever they wanted, while the mice in group B had to eat their food within an eight-hour time

"YOU TRY TO EAT YOUR CALORIES WITHIN A SMALL TIME WINDOW"



window. This meant that there were 16 hours of the day in which they were fasting.

After 100 days there were some remarkable differences. The mice in group A had put on lots of weight and were showing signs of liver damage. Mice from group B had put on far less weight and suffered much less liver damage, despite eating the same amount of food.

So what about humans? So far, the majority of TRE studies have been in rodents, with only a handful of promising human studies. In one of the most recent, Panda and Dr Krista Varady, from the University of Illinois at Chicago, recruited 23 obese volunteers and put them on a TRE diet. Between the hours of 10am and 6pm, they were allowed to eat and drink anything they wanted, but for the remaining 16 hours they could only drink water or calorie-free beverages. The study followed the volunteers for 12 weeks.

After 12 weeks the volunteers had lost about 3 per cent of their body weight and saw their systolic blood pressure decrease. Most had found the diet simple and wanted to continue.

As the problems of obesity continue to mount, we badly need alternative approaches. When I made that original documentary back in 2012 I suggested that intermittent fasting could become something big. I never imagined it would get quite this big. •



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INN OVATIONS PREPARE YOURSELF FOR TOMORROW

CES REPORT 2019



ROLL UP, ROLL UP

Plenty of manufacturers have been working on flexible displays for smartphones and tablets for a while now, but LG stole a lot of their thunder this year by unveiling a 65-inch flexible TV.

Its new flagship OLED 4K TV is big enough to dominate almost any room. But don't worry, when you've finished watching it, you simply hit a switch and the screen rolls up like a poster and packs itself away into the base. As well

as housing the screen, the base also contains a powerful Atmos Speaker System that provides the audio to go along with the TV's visuals. The TV goes on sale this spring and although prices have yet to be confirmed, there's no doubt it will be expensive. But if you want a huge screen that won't take over your lounge, this could be the solution.

LG Signature Series OLED TV R £TBC, lg.com



THE RISE OF SMART, RESILIENT CITIES

Right now, half the world's population live in cities, and that's expected to rise to two-thirds by 2050. In order to make those cities function well, engineers are integrating technology into urban planning to create smart cities — a big talking point at CES 2019. These new technologies will be made feasible by the arrival of 5G, which promises to increased wireless speed and accessibility. Most involve integrating smart technology into urban planning, like a project by American internet provider AT&T who announced they'd be trialling a smart lighting plan in Las Vegas to improve public safety and energy efficiency. Another was by German car company Continental, who presented their electric car-share project, where users access shared vehicles using an app (no need for keys).

They're aiming for a future where we don't own cars, therefore reducing pollution, congestion and noise.

Resilience was another talking point at CES, with the show dedicating a chunk of the floor to technologies that keep communities safe, warm, powered, fed and secure in adverse situations like natural disasters. Watergen was doing just that. They produce large-scale water generators that distil water from the air to create clean drinking water when the usual sources become contaminated. They worked with the American Red Cross to provide water during the 2017 and 2018 hurricanes in Texas and Florida, and their generators are designed to produce 5,000 litres of water per day, which is enough to keep 2,500 people hydrated.

ROBOTS INVADE

Robots were everywhere at CES this year. Some useful, others better off left in a quiet corner. Here are four we'd most want around the house...



FOLDING FRIEND

If you've got a lot of money and some spare space, you could snap up a FoldiMate laundry-folding machine. Feed your shirts into it and it'll fold them perfectly in about five seconds – it can do a whole load in about four minutes. You do have to feed each garment into the machine individually, however, so the novelty might wear off quite quickly.

\$980 (£780 approx), foldimate.com



SMART SUITCASE

Hands-free, smart suitcases usually follow along behind you, which means they're all too easily lost or stolen. ForwardX Robotics has created a smart suitcase that rolls alongside its owner. It uses built-in cameras and facial recognition software to keep an eye on its owner while it dodges all the children, bags, perfume squirters and other obstacles you usually encounter in airports.

ForwardX Ovis Suitcase \$800 (£620 approx), forwardx.com



CUDDLY COMPANY

Groove X, a Japanese start-up, created the Lovot robot to combat the loneliness felt by many of the country's ageing population. It's a soft, cuddly robot that rolls around the house demanding affection from its owner by flapping its arms, and only calms down when it's picked up and stroked. Lovot has over 50 sensors that respond to touch and sound, as well as a head-mounted camera to enable the bot to recognise its owner and avoid collisions with household objects.

Groove X Lovot ¥598,000 (£4,300 approx), groove-x.com



HYUNDAI TO THE RESCUE

Hyundai's new concept car, the Elevate, could be deployed in the wake of natural disaster to save people stranded in places other cars can't reach. Each of its four wheels is attached to a leg, so the car can drive to wherever the road runs out, then start walking to get to those in need. Hyundai claims the Elevate is able to climb over a 1.5m (5ft) vertical wall or across a gap of the same span.

Hyundai Elevate hyundai.co.uk

WHAT'S UP, DOC?

Exercise trackers, such as Fitbit, have been helping people collect their fitness data for a while now, but at this year's CES we saw a raft of new devices that can gather even more information about the state of your health. Some new trackers had integrated ECGs (to monitor heart rhythms) and EEGs (to monitor brain waves), vastly increasing their ability to detect potential problems. Meanwhile, Lumen, a device that analyses your breath, can let you know whether you're burning fat or carbohydrates when you're exercising.

Our favourite health monitoring device at CES was the Heart Guide, made by clinical tech company Omron. It's a

smartwatch with an FDA-approved blood pressure monitor. It works using a similar mechanism as the upper-arm blood pressure monitors we're used to, but is miniaturised in order to work at the wrist. This has various advantages: more frequent measuring makes it easy to find issues that are hard to detect during infrequent doctor's visits, and it also helps avoid the false high blood pressure readings that are common when patients are under stress at doctor's surgeries.

Omron Heart Guide \$499 (£385 approx), omronhealthcare.com



GET SOME SHUT-EYE

CES 2019 was awash with high-tech gadgets to help you get a good night's sleep

DIAGNOSING DISORDERS

For a state-of-the-art diagnostic sleep test, you'd normally have to fall asleep in a lab, while wearing uncomfortable EEG electrodes. The Dreem Band measures the same things as the EEG electrodes: brain activity, heart and breathing rates, eye movement and muscle activity, and claims to be able to use those measurements to teach you to sleep better.

Dreem Band

\$500 (£390 approx), dreem.com

2 LITTLE SPOON

Somnox claims you'll subconsciously synchronise your breathing with the pulses of this soft, kidney-shaped robot as you cuddle it, which can help you drift off to sleep. While we were sceptical about snuggling a robot, it felt surprisingly good, like cuddling a very docile cat. It's got napping functions too, to give you something to spoon during a daytime kip.

Somnox Sleep Robot £499, meetsomnox.com

GET A BLUE BOOST

Light therapy has been used to treat seasonal affective disorder for years, but this is the first time it's been condensed down to the size of a ballpoint pen. PocketSky is a pipe that folds out and wraps in front of your eyes like glasses, shining 'near-natural' blue light into your peepers. It might boost wakefulness and get you back into normal circadian rhythm, but you'll look dorky in the process.

PocketSky

£TBC, pocket-sky.com

SLEEP, CUSTOMISED

With the help of a smartphone app, you can adjust the firmness of each side of Sleep Number's mattresses, so you can doze off on a rockhard slab while your comfort-loving partner can snooze on something altogether softer. The mattress also records biometric sleep data without you having to wear a sensor, and can be used to diagnose conditions such as sleep apnoea and restless leg syndrome.

Sleep Number

From \$999 (£780 approx), sleepnumber.com

⁵ CHILL OUT

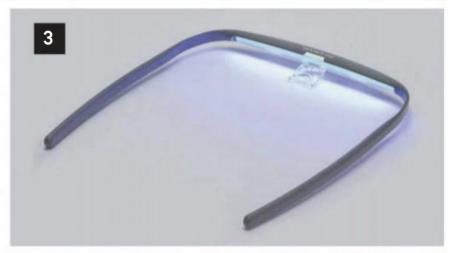
To fall asleep, your body needs to decrease its temperature, which is why flipping your pillow over to the cold side feels so good. Moona has made that feeling last all night by creating a cooling system for your pillow. Set the desired temperature using the bedside control unit, and it pumps water chilled to your preference into a pad that sits in your pillow case, helping you create the perfect conditions to drift off.

Moona Self-Cooling Smart Pillow

£300, getmoona.com





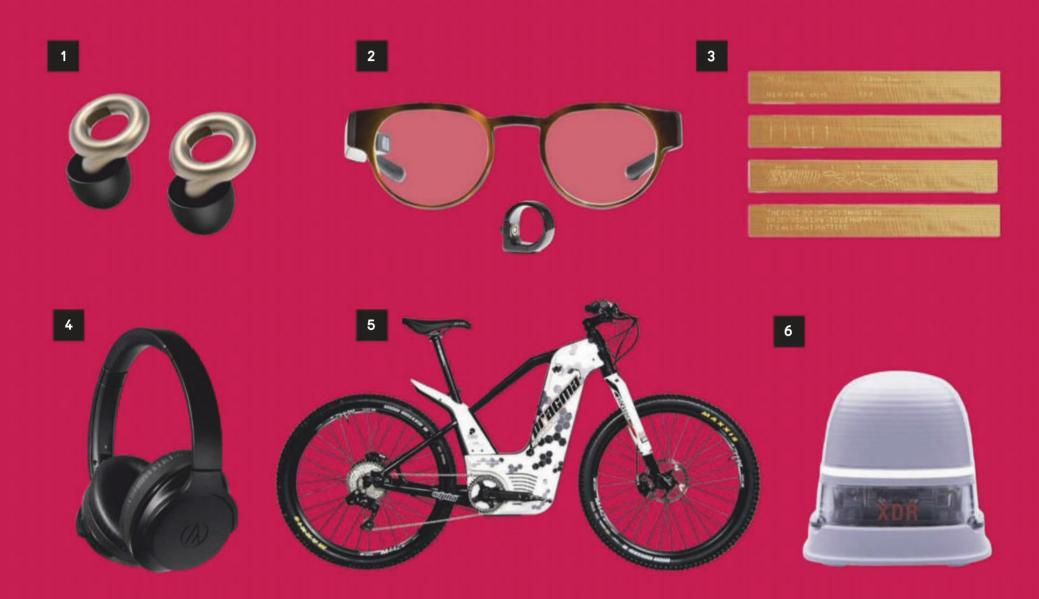






GADGETS WE'D ACTUALLY BUY

Prototypes and concept designs make up a lot of the tech shown off at CES, and are unlikely to make it into the shops in the same form. But here's our pick of the stuff that's ready to buy...



HEARING HELP

These stylish earplugs protect your hearing without ruining the music. The loop on each earplug has been designed to mimic your ear canal but with a reduced acoustic resonance. At the end of each loop is an acoustic filter that lowers all sounds by around 20dB.

Loop Earplugs €29.95 (£26 approx), loopearplugs.com

2 SMART SPECS

North's Focals are normal-looking glasses that have a built-in heads-up display. Inside the right arm is a tiny projector that displays your notifications on the right lens. The glasses are controlled with a ring, which means you won't get sticky fingerprints all over the lenses.

North Focals

\$999 (£775 approx), bynorth.com

3 TECH IN DISGUISE

These aren't just planks of wood, they're touch-sensitive displays that not only show you the time, weather and your text messages, but can also be used to control your central heating and access your voicemail. They even have Google Assistant, so will respond to voice commands.

Mui Smart Display £TBC, mui.jp

4 NO MORE NOISE

Audio Technica's new noisecancelling headphones made the chaotic CES show feel miles away. They use Bluetooth 5.0 to produce a sound as good as any wired pair and they're seriously comfortable. Best of all, their battery life has been extended to 35 hours.

Audio Technica QuietPoint ATH-ANC900BT £269, audio-technica.com

5 HYDROGEN CYCLE

Pragma Industries' new hydrogenfuel-cell-powered electric bikes have a 97km (60-mile) range and take just two minutes to charge. The charging stations are huge though, so the bikes will probably be used for bike-sharing programmes, or for groups like the police.

Alpha 2.0

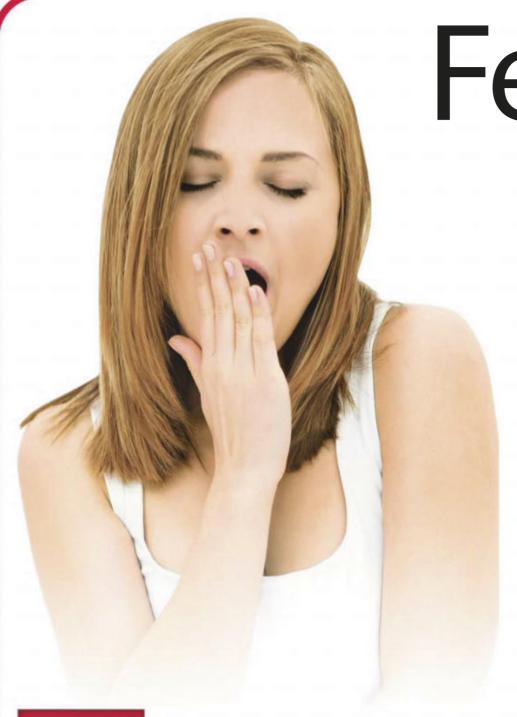
£TBC, pragma-industries.com

6 PRINT ANYWHERE

Printbrush XDR is a small inkjet printer that connects to your smartphone and lets you print whatever you want on whatever surface you like. Just swipe it across a surface and a sensor in the device tracks the direction and prints your image accordingly.

Printbrush XDR

£135 approx, printbrush.com



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INSIDE CHINA'S PLANS TO BUILD A LUNAR BASE

WORDS: COLIN STUART

D

uring the opening days of the New Year, while most of us were still getting over the excesses of the festive period, a huge gap in the exploration of the Solar System was being quietly filled. We'd previously sent probes to every planet in the

Solar System, had close encounters with comets, landed on asteroids and touched down on one of Saturn's moons. On New Year's Day, NASA's New Horizons probe even flew past a Kuiper Belt object more than 6.5 billion kilometres from the Sun. Yet all these things happened before we landed anything on the far side of our nearest celestial neighbour, the Moon. This feat was finally claimed by the Chinese Space Agency with the successful lowering of their Chang'e 4 mission onto the Moon's surface on 3 January. Just 12 hours later, the Yutu 2 rover trundled down a ramp to imprint its tyre tracks in the lunar dust on the Moon's far side for the first time. "It's a hugely significant moment in the history of space exploration," says Prof Ian Crawford, a planetary scientist at Birkbeck University of London.

Chang'e is named after the Chinese goddess of the Moon, with Yutu being her pet white rabbit that is believed to be visible on the surface of the Moon, much like the man in the Moon here in the West. Chang'e 4 marks a return to the Moon's surface after years of human indifference, as we've strived to explore the rest of the Solar System. Interest in all things lunar began to wane after the Apollo missions ended in 1972, with even robotic missions to the Moon's surface fizzling out by 1976. And so it remained until December 2013, when China landed the first Yutu rover on the near side of the Moon as part of the Chang'e 3 mission, making them only the third nation after the US and Russia to successfully dispatch and land a lunar rover.

But the Chang'e 3 mission wasn't without its difficulties, as a technical fault hampered the rover's movement not long after landing. The suspected culprit was more frequent encounters with rocks than

• originally envisioned. Considering these issues, the Chinese space agency's subsequent move was a brave one. "It's quite impressive that their next attempt was on the far side of the Moon," says Crawford.

Due to the Earth's gravitational pull, we only ever see one side of the Moon – the other is permanently turned away from us. That's why Chang'e 4 landed during a new Moon, a time when our side is dark and the far side is completely illuminated by the Sun. Regardless of which side they land on, missions to the Moon have to endure two weeks of cold darkness, followed by a fortnight of intensely bright daylight. The only way to learn more about the far side is to send probes (or people) around the back for a closer look. While the first image of the far side was taken in 1959, it has taken until now to land a probe on it. NASA rejected the idea of sending Apollo 17, the last human landing mission, there in the 1970s, partly due to the difficulties with communication – the Moon itself blocks direct radio signals with Earth.

LUNAR LANDING

To get around the communications problems, the Chinese parked the Queqiao (Magpie Bridge) satellite in lunar orbit last year to relay messages back home. Queqiao orbits 65,000 kilometres beyond the Moon and transmits signals back to China and other base stations around the world. This system makes the mission more of an intricate ballet than near side landings. Mission scientists spent four weeks prior to touchdown testing out this crucial relay system. The far side is also far more jagged compared to the relative smoothness of the near side, meaning there are even more potential hazards to avoid on landing. According to Prof Bernard Foing, executive director of the International Lunar Exploration Working Group, success required "a number of critical manoeuvres including launch, trans-lunar injection, lunar capture, de-orbiting, stabilisation and controlled descent, hazard avoidance, soft landing, the deployment and commissioning of rover and instruments." It all seems to have worked perfectly. "The whole process was as expected, the result was pretty precise and the landing was very stable," chief designer Sun Zezhou



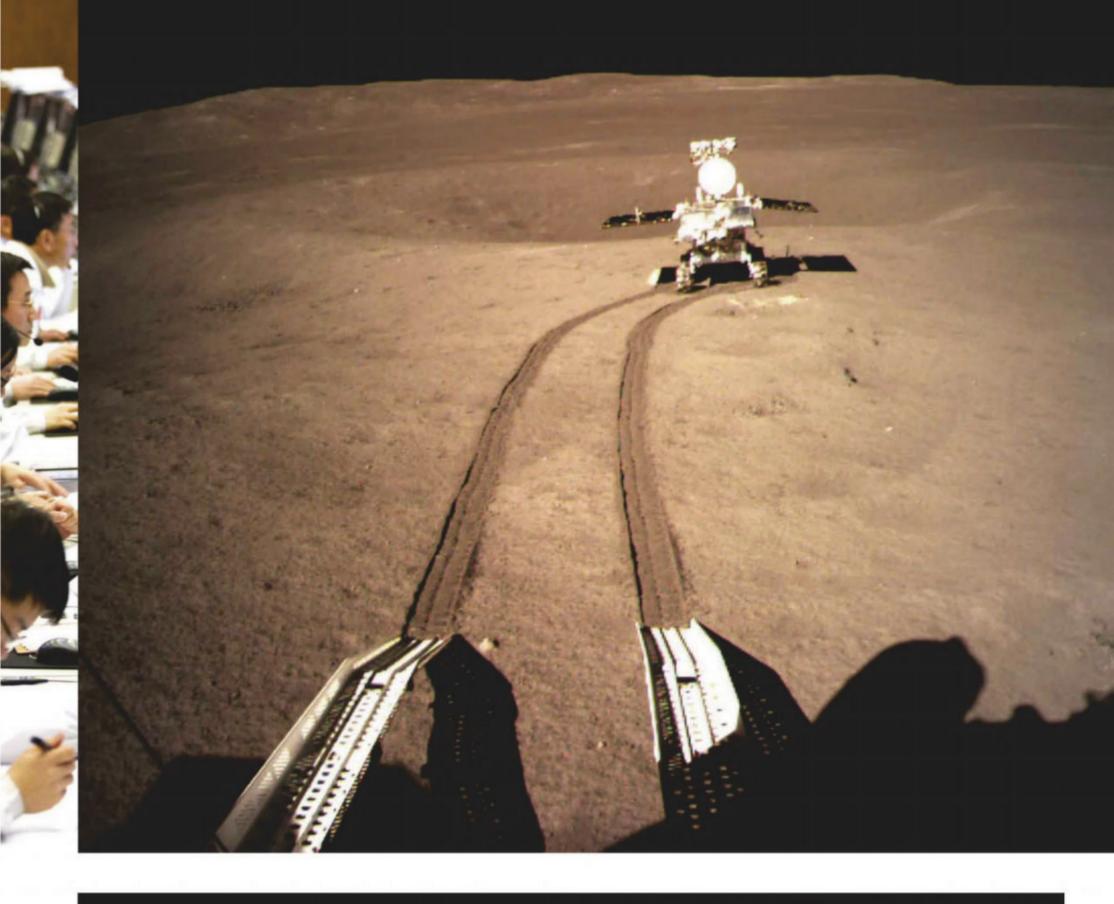
ABOVE: Technicians at Beijing's Aerospace Control Center celebrate Chang'e 4's successful landing on the Moon

ABOVE RIGHT: Selfie time! The Yutu 2 rover trundles across the Moon's surface, making fresh tracks as it goes told Chinese state media shortly after confirmation of success reached home.

Their chosen landing spot was the 180km-wide Von Kármán crater, named after aerospace engineer Theodore von Kármán who made many key advances in the field of aerodynamics in the 20th Century. It's an impact site superimposed on a much bigger collision scar known as the South Pole-Aitken basin. "It is the Moon's largest, deepest, and oldest impact structure," says Foing. Place Mount Everest on the crater floor and its peak wouldn't be close to poking out over the top. It's of extreme geological interest as it could provide clues about the way the Moon formed from debris thrown into space after a small planet collided with the infant Earth. The crater was flooded with lava during the Moon's early days, meaning the crater floor is incredibly smooth and far less dangerous to land on than elsewhere on the far side. "It was very much chosen with safety in mind," says Crawford.

The colossal impact that formed the Aitken basin could well have penetrated deep into the Moon's mantle, exposing deeper basalt material onto the surface. "No one has ever measured the composition of •

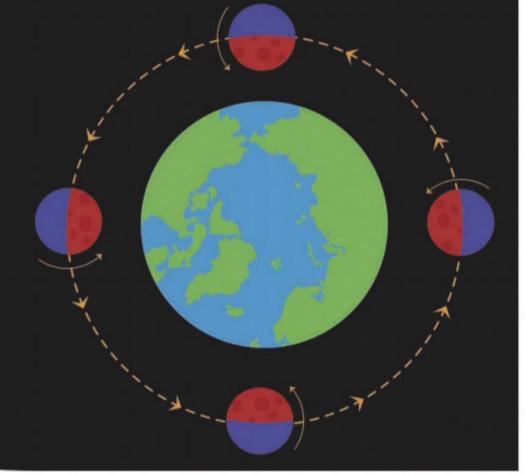
"WHILE THE FIRST IMAGE OF THE FAR SIDE WAS TAKEN IN 1959, IT HAS TAKEN UNTIL NOW TO LAND A PROBE ON IT"



WHY DO WE ONLY EVER SEE ONE SIDE OF THE MOON?

Thanks largely to Pink
Floyd's 1973 album,
astronomers regularly
contend with talk of the 'dark
side of the Moon'. There isn't
one. At least there's no
permanently dark side of the
Moon. It is true that we only
ever see the front of the
Moon and not the back due
to an effect called tidal
locking. Over time the Earth's
gravity slowed the Moon's
rotation on its axis until it
matched the time it takes to

orbit us (both 27.3 days). So the Moon is rotating, we just never see the other side. The Moon is always half lit up and half not (day and night, just like on Earth). Where this sunlight falls depends on the Moon's position around the Earth. When between us and the Sun, the back is completely illuminated – definitely not dark. The only time it is completely dark is when we are experiencing a full Moon.



SPACE SINUS IRIDUM Chang'e 3 landing site MARE FRIGORI Plato MARE IMBRIUM **Archimedes Aristarchus** (Eratosthenes Copernicus **Ptolemaeus** Clavius

LANDINGS AND CRASHES ON THE NEAR SIDE OF THE MOON



• far side basalt before," says Crawford. Doing so crammed onto the back of Chang'e 4 and carried to isn't a certainty, however, as the interesting stuff the Moon. The far side of the Moon is considered might have been covered over by the lava flows that by many astronomers to be an ideal place to build a flooded the basin. Like any space mission, Chang'e 4 scientists had to balance risk and reward. So they included another way to get data on the Moon's subsurface – the Yutu 2 rover carries an instrument called Lunar Penetrating Radar (LPR) that can scan the structure of the lunar far side down to a depth of 100 metres.

Geology is far from Chang'e 4's only aim. A wide array of other experimental instrument were also

radio telescope. Sheltered from the background hum of the Earth by the Moon itself, any observatory there would be free to make sensitive measurements of faint astronomical radio signals. Chang'e 4 includes an instrument capable of listening to space across a wide range of frequencies. Should its results prove fruitful, Crawford believes it could usher in much more sophisticated radio astronomy missions in future. However, the majority of Chang'e 4's •

ON THE MOON

There could be rich rewards on the lunar surface

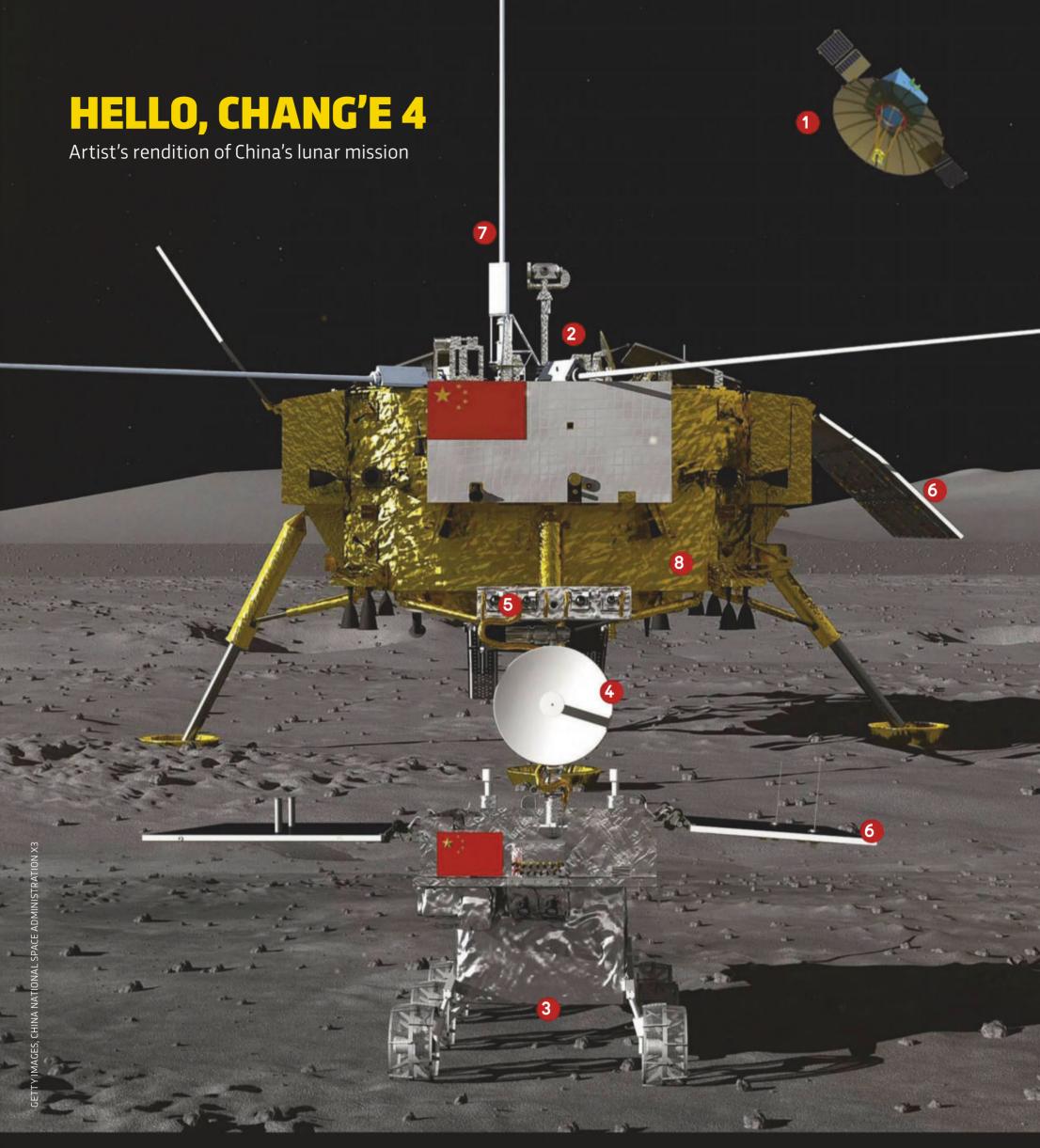
Why mine the Moon? The Moon has a mass of 73 trillion tons. A crude calculation shows that if one ton of material were removed each day, it would take 220 million years to deplete the mass by 1 per cent. This isn't enough to cause a change in the Moon's orbit, or affect the gravitation that influences the tides on Earth. Geological surveys of the Moon show that it contains several vital elements that are in increasingly short supply on Earth. These include:

Helium-3

This substance is an isotope of helium that is made up of two protons and one neutron, rather than the two protons and two neutrons that comprise the more common helium-4. Though rare on Earth, helium-3 is relatively abundant in the Moon's soil and rock. It could play an increasingly important role in the future developments of energy generation, particularly as an energy source to power nuclear fusion reactors.

Rare earth metals

These 17 elements are commonly used in smartphones, computers and medical equipment. Rare earth metals are vital to emerging technologies, but around 90 per cent of the world's supply is produced in China, and experts say they have just 15 to 20 years' worth of supplies left. The Moon may become an increasingly important source of rare earth metals as supplies dwindle here on Earth.



1Relay satelliteThis is positioned
65,000 kilometres beyond the lunar surface to bounce signals back to Earth.

Dosimeter

This measures the radiation on the lunar far side, in preparation for future human $missions \, to \,$ the Moon.

Ground-

penetrating radar This can scan underneath the lunar surface, right down to a depth of 100 metres.

4 Transmitter dish This sends scientific data and images from the Yutu 2 rover to the relay satellite.

Panoramic

camera This has already sent back stunning images of the landscape on the far side of the Moon.

6 Solar panelsThese provide power to the rover, but only during the two weeks every month when the far side is illuminated.

7 LFS booms This trio of five-metre-long antennae pick up radio waves from the early Universe, just after the Big Bang.

Lunar Micro

EcosystemThe lander carries this small biological experiment containing various seeds along with silkworm eggs.





• non-geological experiments are designed to scope out the possibility of future human missions back to Moon. According to Foing, one experiment called ASAN, "will study how the solar wind interacts with the lunar surface and perhaps even the process behind the formation of lunar water." The South Pole-Aitken basin is thought to be home to large quantities of water ice – a crucial resource for tomorrow's Moon dwellers. Would-be astronauts will also be unprotected from the harshness of space. They'd be prone to sizeable doses of radiation from solar storms and cosmic rays generated by stars exploding elsewhere in the Galaxy. The Lunar Lander Neutrons and Dosimetry (LND) experiment, developed in collaboration with Kiel University in Germany, will assess the strength of that dose in the vicinity of Chang'e 4's landing site.

LIFE ON THE MOON

Yet the experiment most likely to fire our collective imaginations is the Lunar Micro Ecosystem. This sealed cylindrical container is 18 centimetres long and weighs just three kilograms. Among its contents are various seeds, along with silkworm eggs. A tiny camera will keep watch to see if these living things can eke out an existence in the harsh, alien environment they now find themselves in. At the time of writing, cotton seeds had already sprouted (for more on this, see p15). Decades from now, humans could look back at this experiment as the beginning of life on the Moon. Make no mistake that is what China is gearing up for. Their recent launches are following roughly the same pattern as NASA before the Apollo era. First launch satellites to the Moon (Chang'e 1 and 2), then land a rover on the near side (Chang'e 3). This new far side landing is a real show

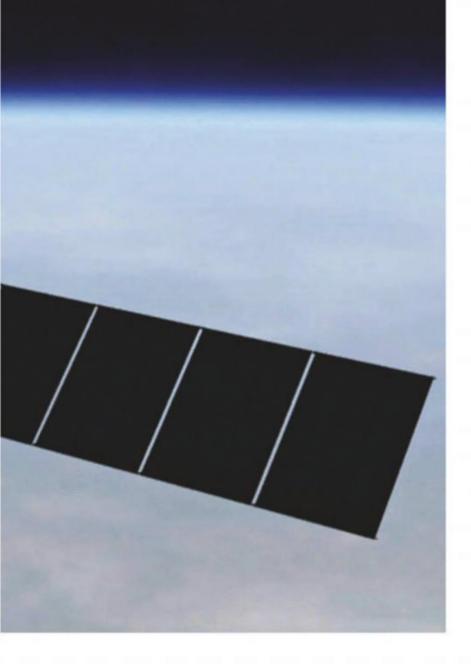
ABOVE LEFT: Yang Liwei, the first Chinese astronaut (also called a taikonaut), waves to the crowds after stepping out of the Shenzhou-5 re-entry capsule in October 2003

ABOVE: Tiangong-1, China's first space station, orbited the Earth between 2011 and 2018

"DECADES FROM NOW, HUMANS COULD LOOK BACK AT THIS EXPERIMENT AS THE BEGINNING OF LIFE ON THE MOON"

of intent. "The Chang'e 4 mission will advance [their] technical maturity for future robotic and human landings," says Foing.

China wants to be considered in the same league as the US and Russia when it comes to space exploration. Yang Liwei became the first Chinese astronaut (also called a taikonaut) in 2003. So far, 12 taikonauts have been into space, some of whom were sent to a prototype Chinese space station called Tiangong-1, which remained functioning around Earth from 2011 to 2018 before falling from orbit over the southern Pacific Ocean and reportedly burning up in the atmosphere. Now, the Chinese have begun the construction of a new, more ambitious orbital outpost in a bid to match the stature of the long-established International Space Station. They hope to have it finished by 2022. What they learn there, combined with the lessons from Chang'e 4, could see China send the first taikonauts to the Moon as early as 2025. In the meantime, more robotic missions are already in the pipeline. "Their next steps will be Chang'e 5 and 6," says Foing. The



former could launch as early as December 2019 and will aim to return samples of lunar material from the near side. Success will demonstrate that the Chinese can return material from the Moon, paving the way to bring humans back too. "A number of other robotic landers are planned that could build up a de facto lunar robotic village," says Foing.

SPACE RACE

There is another potential advantage to be gained from the recent Chang'e missions. No other country has landed anything on the Moon since the 1970s. Having readily available technology to do so could place China in the lead to exploit the Moon's natural resources. By analysing the composition of the lunar far side, they could gain valuable information about the kind of treasures potentially on offer. The Moon is already thought to contain significant amounts of helium-3, which is a chemical that's exceedingly rare on Earth. What else could they find squirrelled away in these unexplored rocks? Could a modern space race be triggered as superpowers compete once again for off-Earth supremacy? Some quarters are nervous about what it could mean for the potential Chinese militarisation of space. The country is party to the 1967 Outer Space Treaty, which forbids signatories from placing weapons of mass destruction on the Moon. However, China has previously flexed its space muscles, most notably when it destroyed one of its own weather satellites in 2007 using a missile fired from the ground. While other space agencies have been quick to congratulate the Chinese on their latest success, and talk openly about potential joint projects, it remains to be seen whether the future will be more about competition or cooperation. •

THE NEW SPACERACE?

The success of China's Chang'e 4 landing has again brought the country's space programme into the spotlight, and raised the question whether China is now a serious player in space exploration. The answer is unequivocally 'yes'. While it is easy to rebuff these latest accomplishments by pointing out that the United States and Russia landed spacecraft on the Moon more than half a century ago, this misses the point.

Though they did not generate as many column inches as Chang'e 4, there were 39 Chinese rocket launches in 2018, only one of which failed. In comparison, Russia launched 20 rockets, with one failure; and the United States launched 34, all successful. Europe lagged behind with eight launches with one failure, while Japan and India launched six and seven rockets respectively. It looks likely that China's position will become increasingly difficult to ignore, particularly as the country is open for collaboration - Chang'e 4 carries experiments from Swedish, German, Dutch and Saudi Arabian researchers. In 2017, the Chinese announced plans for a permanently crewed space station as part of their Tiangong or Heavenly Palace programme. Notably, the country signed an agreement with the United Nations to allow experiments and astronauts from other countries to use the station. The core module of the space station is planned to be launched in 2020 with proposals for collaborations coming from 27 countries. It's

unlikely, however, that the US will be involved as Congress banned NASA from using its funds to host Chinese visitors in 2011. This division between the superpowers leads to the question of rivalry and whether China's interest in the Moon will spark a new space race. It's complicated. The same team of space agencies responsible for the International Space Station (NASA, ESA, Russia's Roscosmos, Japan's JAXA, and Canada's CSA) are already developing the Lunar Orbital Platform-Gateway (LOP-G). LOP-G is a space station that would carry a four-person crew in an orbit around the Moon, sometime after the mid-2020s. But there are those who say it is a costly distraction from sending astronauts to Mars. So if anything, the Chinese interest in the Moon could lead these critics to call for efforts to be concentrated on Mars, in order to reassert NASA's lead in space. Such a plan, however, would inevitably bring NASA into disagreement with its international partners, all of whom are known to favour going to the Moon.

So the future is going to be interesting. Unlike the space race of the 1960s, when the United States and Russia went head-to-head to land on the Moon, we are likely to see two parallel space programmes develop, one led by NASA and the other by the Chinese. And although we are unlikely to see direct rivalry in their goals, you can be sure that both sides will be keeping an eye on each other.

Colin Stuart is an astronomy writer. His latest book, *How To Live In Space* (£16.99, Andre Deutsch), is out now. He tweets from **@skyponderer**

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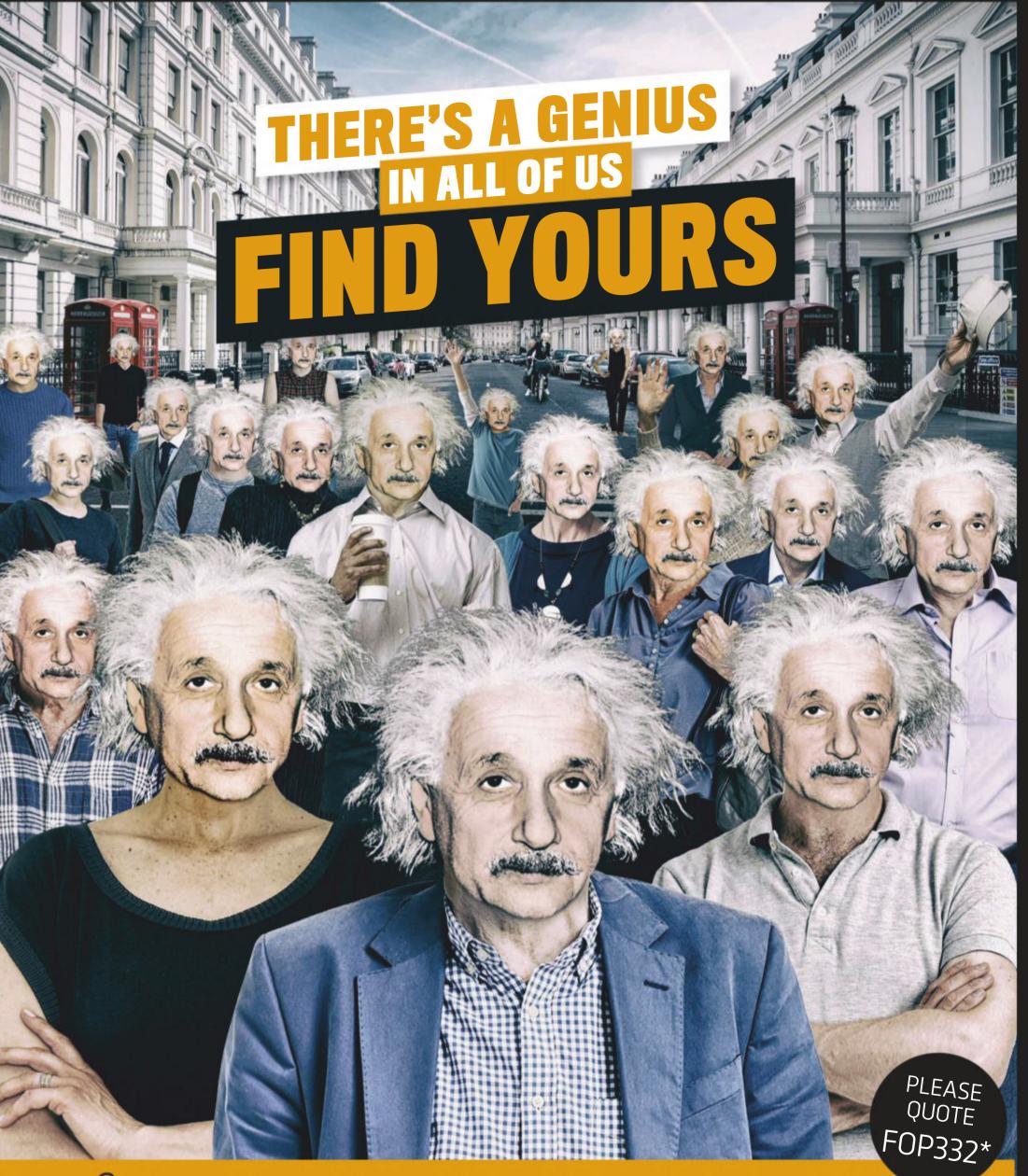
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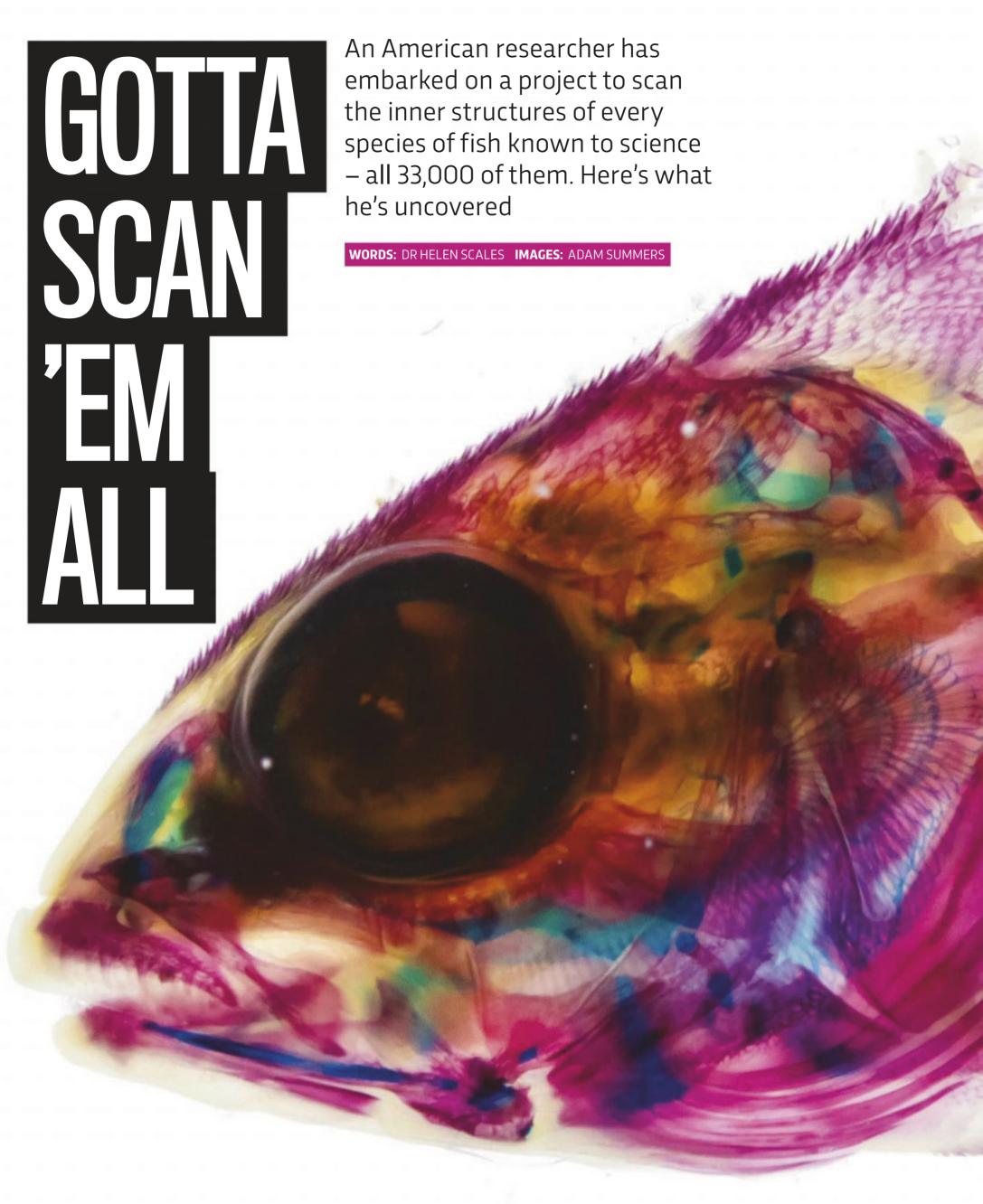
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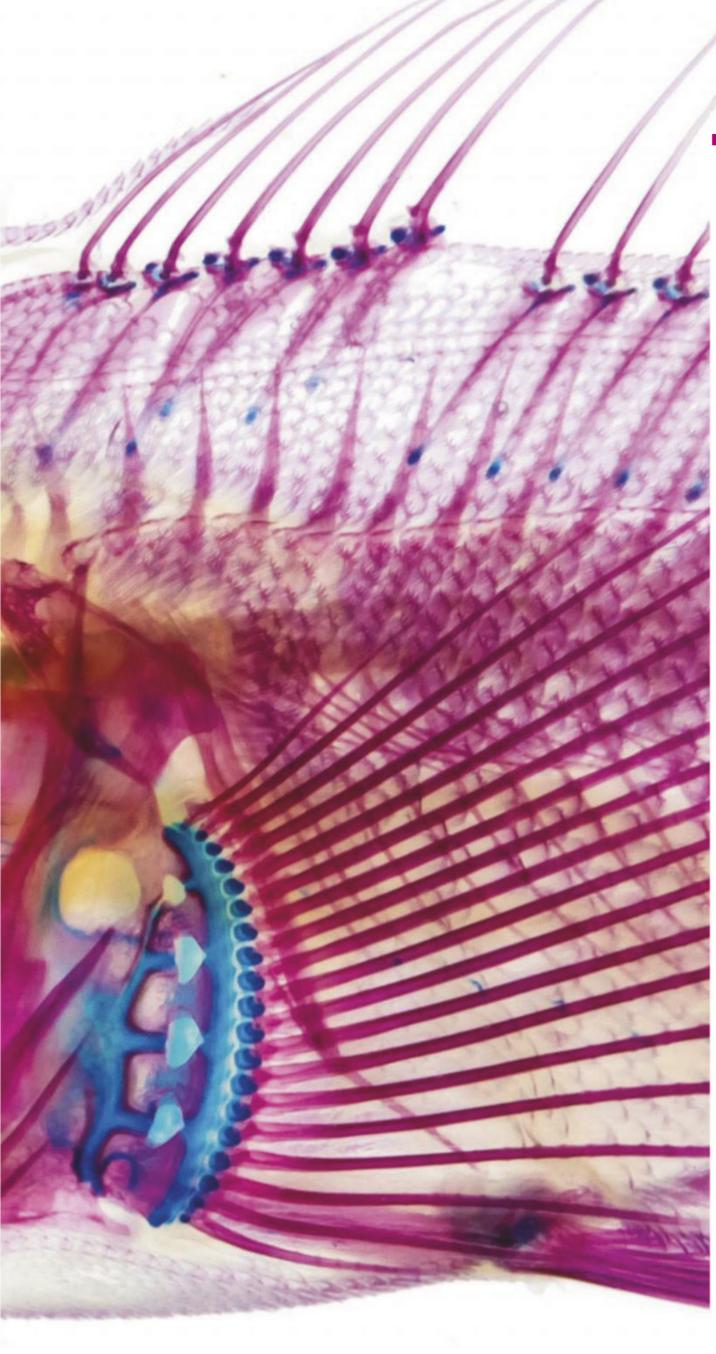
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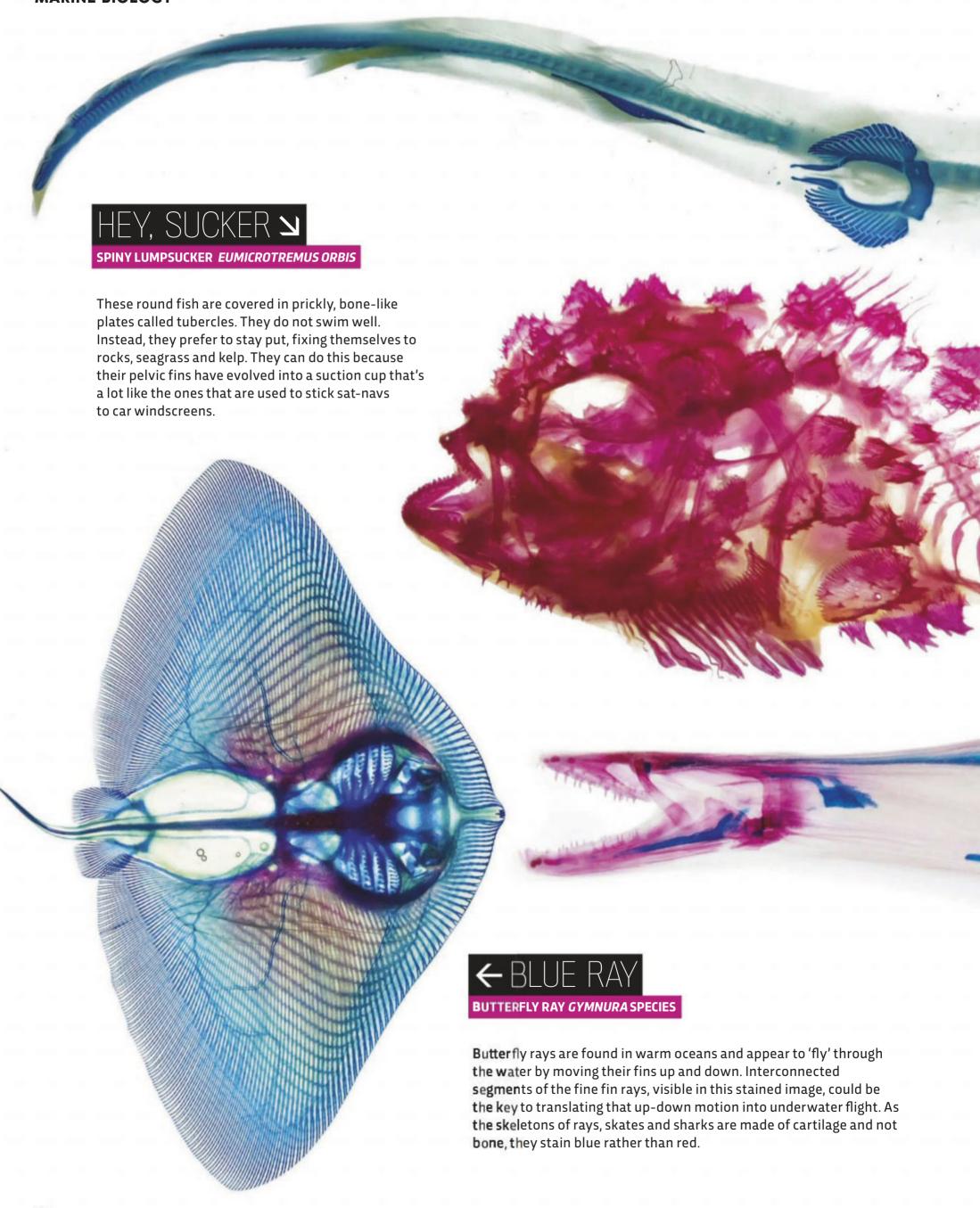
here is a small lab on Friday
Harbour, San Juan Island, just off
the US state of Washington. Here,
marine biologist Adam Summers
spends much of his time painstakingly loading
fish after fish into a CT scanner to produce
detailed images that reveal their intricate
skeletons and inner structures. The project
began inauspiciously several years ago when
Summers would pay covert night-time visits
to local hospitals, begging to use their CT
scanners during periods of downtime. "We
would stuff dead sharks and rays and things
into bags, so nobody could tell what they
were," he says.

After amassing a library of several successful scans, he began sharing his results on Twitter. To his surprise he got a huge response, with many biologists asking him to scan their favourite fish. "I jokingly replied that I was going to #ScanAllFish," he says. At the time, he didn't really believe that would happen because it was taking 12 hours to scan three or four fish, and there are more than 33,000 species to get through. But with the current total of scans standing at 3,827 he reckons the project could be completed in as little as two years, though they may have to skip a few of the biggest, rarest fish.

Thanks to the success of his images, Summer applied for a grant for his own CT scanner, which has been installed in his labs. Every scan is immediately posted online for anyone to use, with Summers not asking for any credit. The project has already racked up more than half a million downloads, with everyone from scientists and engineers to artists and teachers using the images. "We're exposing our data to a world of people who have great brains and will do far better things with it than we ever could," he says.

Anyone can use the scanner to scan their favourite species, provided they make the data freely available. "If you come to the island you can bring a suitcase full of dead things and CT them," says Summers. He is also collaborating with museums worldwide to scan their collections. It is hoped that these 'digital dissections' will allow people to see inside fish and manipulate them in ways that is just not possible with preserved specimens.

As well as CT scans, Summers also makes fish skeletons visible through their skin using dyes that stain bone red and cartilage blue. He bleaches the fish white with hydrogen peroxide and dissolves its flesh with the digestive enzyme, trypsin, leaving only skin and connective tissue. The fish is then photographed while immersed in glycerine, which renders the unstained parts invisible. •

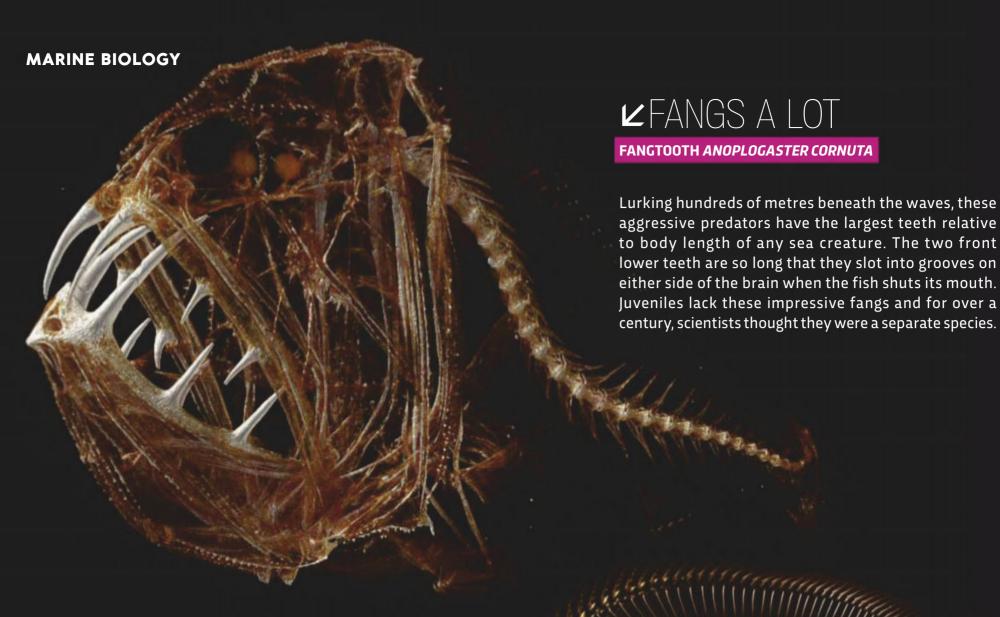








Relatives of seahorses, tube-snouts are the size of pencils and often swim together in large schools. The females are drab and well-camouflaged, while the males have shining patches on their snouts and bright red fins. Females lay eggs on kelp, sticking them in place with goo secreted by their kidneys. Males then guard the nests against predators.



NUTTY GNASHERS↓

PIRAPITINGA PIARACTUS BRACHYPOMUS

The chomping teeth of these fish make them look like they stole a set of human dentures. Though related to piranhas, pirapitinga are harmless herbivores that chew on seeds and nuts. They belong to a group of fish called the serrasalmids, which are well ahead in the race to #ScanAllFish, with 50 out of 90 species already in the database.



CATCH A BUZZ->

SPOTFIN HATCHETFISH THORACOCHARAX STILETTOS

Hatchetfish frequently leap from the water. The buzzing sound they make while flying through the air led people to believe they flap their fins as wings. In fact they glide, holding their fins still. A quarter of their body mass is made up of huge pectoral muscles, giving them pre-flight propulsion. The deep belly adds stability during take-off and landing.



HOGCHOKER TRINECTES MACULATUS

Like all flatfish, hogchokers begin life as larvae with a normal, upright stance and one eye on each side of the body. Then comes a point when one of their eyes gradually slides over the head to join the other. It can be either eye that moves, but in the case of the hogchoker it's the left.



ARE ACCENTS DYING OUT?

Our speech is changing, and innovative research using social media and smartphone apps is giving us a new insight into why and how this is happening

WORDS: ANDY RIDGWAY

here is a debate that divides our nation. It's the source of countless arguments in workplaces and schools around the country. How should you say the word 'scone'? Should it rhyme with 'gone' or 'own'? Your answer will depend on where you're from. If your pronunciation rhymes with 'gone', you're more likely to be from southern Britain, northern England or Scotland. If it rhymes

with 'own', you're probably from the Midlands.

The words we say and how we say them have pinpointed where we live in the British Isles for generations. They're an integral part of our identity, tying us to the places we feel closest to and the social class we inhabit, and they come with plenty of social and cultural baggage.

But although regional dialects (the words we use) and accents (how we say them) are widespread around the world, there are whisperings that their days are numbered. After all, few of us remain in

days are numbered. After all, few of us remain in the same town or city all of our lives, and we're exposed to countless accents every day, whether on the bus or on Netflix. Does this mixing of influences mean that regional differences will soon become a

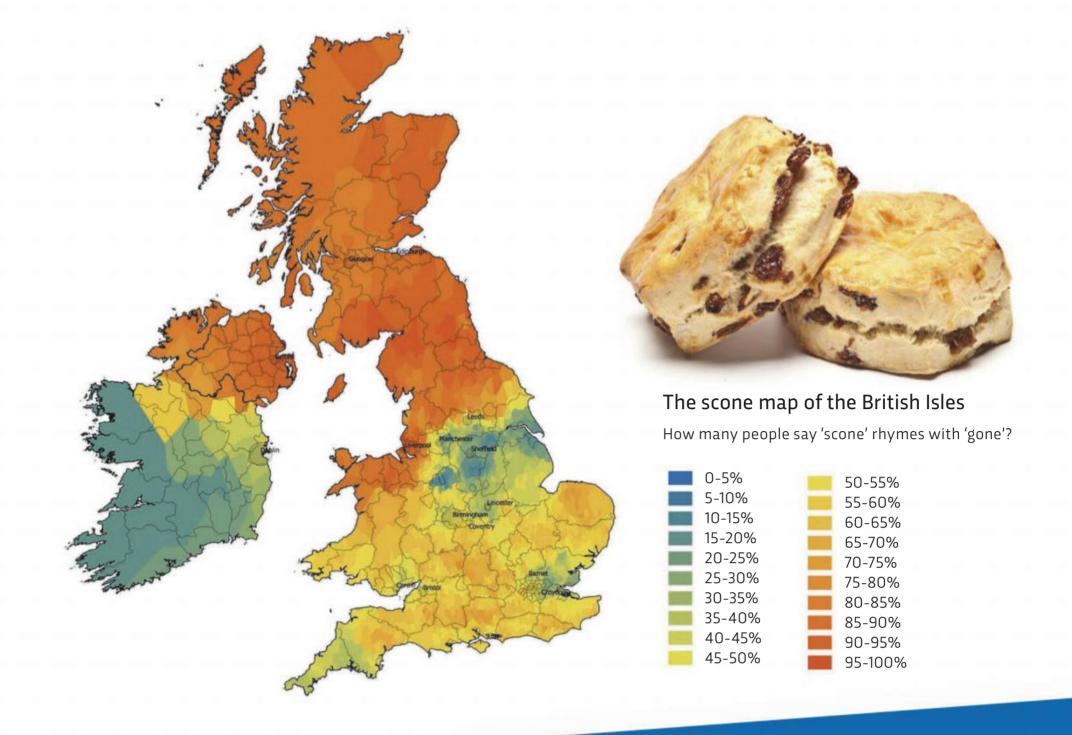
thing of the past?

Thanks to the reams of data generated by social media platforms such as Twitter, and new ways of tracking accents using smartphone apps, we're beginning to understand more about how the way we speak is changing. And it's throwing up some

surprising results, revealing not only that accents are evolving, but that entirely new ones are springing up.

Traditional methods for studying dialects and accents involved researchers traipsing around the country armed with microphones to carry out lengthy interviews. Now we have instant, big data linguistics. Prof Jack Grieve, an expert in language variation at the University of Birmingham, recently completed a research project that involved analysing 200 million tweets made up of 1.8 billion words posted from around the UK in 2014. By matching the tweets to their location, he could create maps of different words, and then compare these to similar maps compiled as part of the BBC Voices project – an online survey of accents and dialects carried out between 2004 and 2007. Importantly, the maps tended to match up - validating Grieve's use of Twitter data – and one thing came through loud and clear: regional dialects are still going strong. "You clearly see north/south differences in the words we use, and you can see Wales, Scotland and Northern Ireland popping out in the data," says Grieve, in a Canadian accent. So, for example, while 'sofa' is predominantly used in the South, it's 'settee' in the North and Midlands, and 'couch' in Scotland.

Grieve's Twitter research is also revealing how the words we use are changing. Humans are constantly inventing new words and phrases to help us express ourselves and create a sense of community and belonging. By analysing nearly nine billion words tweeted across the US in 2013 and 2014, Grieve



was able to pinpoint where new words were being 'born', and how they were spreading. He found, for example, that 'baeless', which means to be single, originated from the Deep South; 'mutuals', for people who follow each other on social media, emerged from the US West Coast; and 'lit', for something that's good or impressive, first surfaced in New York. Next, Grieve plans to look at tweets from the UK, to see if he can find new words that are emerging and spreading here, too.

DIGITAL ACCENTS

So what about accents? Surprisingly, Twitter can tell us about these too, and it's all down to the way we spell. "You get a lot of creative spelling on Twitter," says George Bailey, a phonetics expert at the University of York, in a gentle Mancunian accent. Many people type words as they would pronounce them. In Manchester, for example, some people type 'city' as 'citeh', which is a stereotypical Mancunian pronunciation.

Some changes in how we speak in the UK are already evident. Take what linguists call 'th-stopping'—a change in the way 'th' is pronounced, where, for example, 'thing' becomes 'ting'. "This most likely emerged in London, but you find it used on Twitter all across the country, probably because it's been adopted in lots of different regions and in lots of different subcultures," says Bailey.

A question that is yet to be answered is the extent to which the spelling of words in Twitter is a genuine •

WHAT'S IN AN ACCENT?

People can be judgmental about the way we speak

The trustworthiness and competence conveyed by the Scottish accent are said to be a significant factor behind the decision of so many companies to locate their call centres there. And when plans were announced for Carpeo Estate Planning, a will and funeral planning business, to open a call centre in Newport in 2017, the 'sympathetic and consoling' Welsh accent was said to be a factor behind the decision.

Accents have a big influence on how we perceive each other. "People who speak standard English tend to be rated highly on [their likelihood of] having a good job and a good house, but they tend not to be rated as likeable," says Dr Natalie Braber, a linguistics expert at Nottingham Trent University. Different levels of intelligence, attractiveness, trustworthiness and friendliness have all been linked to different accents in polls and studies.

So where do these perceptions and subconscious judgments come from? "If you get non-English speakers to listen to various accents from around Britain, they don't rate one as better than the other," says Braber. "So there's nothing inherently nicer sounding about one accent compared with another, it's just our associations – we think that people from certain places have certain character traits associated with particular stereotypes, so we transfer that to the way they speak."

Those perceptions are real, though, and in a 2013 poll by research consultancy ComRes, 28 per cent of interviewees said they felt they had been discriminated against because of their accent. So maybe we should celebrate all accents, and avoid making snap judgments about them that may well be wrong.

◆ reflection of how someone would say them out loud. "A lot of the time in speech, the way we pronounce words is relatively subconscious, but you have to make a deliberate choice to spell these words in that way on Twitter," says Bailey. To find out how closely the two match would require recording how people speak while also tracking their use of language on Twitter – something that's yet to be done.

FORCES OF CHANGE

In the meantime, though, a smartphone app is revealing more about how our accents are changing. The *English Dialects* app, developed by Dr Adrian Leemann, an expert in language variation at Lancaster University, was downloaded by 50,000 people soon after it was launched in 2016. Users are asked questions about how they pronounce certain words, and their responses are compared to the Survey Of English Dialects – an influential study carried out between 1950 and 1961. The results so far are intriguing. "There has been a substantial levelling towards aspects of the southeastern English accent across much of the West Country, Midlands and the North," says Leemann. In other words, many northerners today are speaking more like southerners – at least in some aspects of their accent.

Take the strong pronunciation of the 'u' in words like 'but' and 'butter' – a typical northern English feature.

"I don't think accents and dialects will die out because they're too big a part of who we are. But we do find some traditional rural dialects are disappearing because people are living a lot more in the cities"

"This feature appears to be slowly disappearing in the North," says Leemann, who describes his accent as Swiss with a strong North American influence. "It's still very much there, but we find a big change compared to the 1950s." The softer, southern 'u' is now much more widespread.

These accent changes are seen in some people more than others. Analysing data from seven northern English cities, including Leeds, Liverpool and Manchester, Leemann found a distinct pattern in the pronunciation of 'u'. "It tends to be highly mobile people who use the more southern vowel pronunciation," says Leemann. So those who have travelled around the country more, for work or



study, have the most levelled accents. Intriguingly, there's also a difference between the sexes, with women more likely than men to use the southern pronunciation. "It's women leading the change," says Leemann.

The levelling of UK accents is also seen in a feature known as 'rhoticity': how strongly the 'r' is pronounced in words such as 'arm'. (Comedians Russell Howard and Stephen Merchant are examples of more heavily 'rhotic' speakers.) Results from the app show that a distinct 'r' is heard today in the West Country and in Lancashire around Preston and Bolton, as it was in the 1950s, but it's now much less widespread elsewhere in the country (it used to be heard as far eastwards as Oxford and Reading).

Taken together, the changes in UK accents revealed by the *English Dialects* app paint a complex picture. But overall, this project suggests that there's a definite levelling going on, with regional differences becoming less marked. Leemann has used his app to study accents and dialects in other countries, too. "In Germany and German-speaking Switzerland, you also find levelling patterns," he says. In Switzerland, for example, it's the dialect spoken in Zurich that is spreading.

MELTING POT

In the US, there's evidence of even more extreme accent change. In the town of Liberal in southwest Kansas, a completely new accent has been developing since the 1980s. The town has gone from a 20 per cent to a 60 per cent Latino population in a couple of decades. This influx of Spanish speakers has given the accent a distinctly Spanish twang, even among those who don't speak Spanish.

Entirely new accents are forming elsewhere in the US, too, in what's being described as the 'northern cities vowel shift'. In cities around the Great Lakes,



ABOVE: Name that accent! From left: Rab C Nesbitt, played by actor Gregor Fisher; musician Liam Gallagher; comedian Russell Howard (Glasgow, Manchester and Bristol, respectively)

such as Chicago, Buffalo and Cleveland, the way vowels are pronounced is changing. So, for example, 'bit' is being pronounced more like 'bet', and 'bet' is pronounced more like 'but'. There's no agreement on what's causing it, but one theory is that it all started with an influx of German-accented English speakers way back in the 19th Century, which is still having a knock-on effect on local accents today.

Shifts in accents don't always happen in a smooth geographical transition. "Sometimes you see changes skipping from city to city, missing out the countryside in-between," says Dr Natalie Braber, a linguistics expert at Nottingham Trent University, in a western Scottish accent. This might be because accents are slower to change in rural areas. "Small villages have fewer people migrating into them than cities, and so there's less contact with outside groups who bring their accents with them," says Braber.

A prime example can be seen with Multicultural London English (MLE), in which the speech has Caribbean, West African and Asian elements. Here, vowels in words like food, blue and crew are produced further forward in the mouth with a more distinct 'oo' sound, and there's also th-stopping, among other features. While it started in London, aspects of MLE are now spreading to other cities. A project at Manchester Metropolitan University, for example, found several aspects of the MLE accent in younger Mancunians. Other research has shown a feature known as 'th-fronting', where the 'th' sound is replaced with an 'f' or 'v', such as 'fink' for 'think', and 'bave' for 'bathe', has also been spreading northwards from the southeast, skipping from city to city.

ACCENT OF THE FUTURE?

So does all this levelling and mingling mean that accents and dialects are slowly dying out? "I think 'evolving' is a better way to describe what's happening," says Braber. "I don't think accents and dialects will die out because they're too big a part of who we are. But we do find some traditional rural dialects are disappearing because people are living a lot more in the cities. But there's no way you would ever mistake someone from Liverpool with someone from Birmingham."

Exactly where this will lead us is hard to say, but a report, *The Sound of 2066*, written for the HSBC bank by speech scientist Dr Dominic Watt at the University of York and accent coach Brendan Gunn, provides a snapshot of what our accents will be like in 50 years' time. It predicts that the biggest change will be in Britain's cities, with extreme versions of the changes we're already seeing. The standard 'th' sound will be lost altogether in London, says the report, with th-stopping and th-fronting completely dominating. It also says that, by 2066, the northern 'u' vowel will be the same as the southern version, or at least there will be a 'fudged' version somewhere between the two.

Long-term predictions aside, it's the link between how we speak and who we are that makes this such a fascinating area of research. In her work, Braber is frequently asked how words 'should' sound. "Sometimes people are worried that they might give the wrong answer," she says.

But, in truth, there are no right or wrong answers – no right or wrong ways of saying things.

Unless the word is 'scone', then it clearly rhymes with 'own'. •

Andy Ridgway is a freelance science writer based in Bristol, who speaks with a northern accent.





Some people cannot imagine their best friend's face, or even their own house. This lack of mind's eye is called 'aphantasia', and researchers are only just starting to unrayel the science behind it

WORDS: DR LUCY MADDOX ILLUSTRATIONS: JAMES MINCHALL



icture an apple. What colour is it? What about calling to mind your mother's face? What is her expression? How about your last holiday? Can you picture where you stayed? For some people, this is impossible. They cannot recall

images of familiar objects or people to their 'mind's eye'. In effect they don't have one. This crucial difference in the way people see the world has only started to be researched in the last few years. How have we gone for so long ignoring this variation in how we experience our internal worlds?

MIND BLIND

Aphantasia is the name given to the inability to call an image to mind. The name was coined in 2015 by Prof Adam Zeman, a cognitive and behavioural neurologist at the University of Exeter. Zeman first became aware of the phenomenon when he was referred a patient who had 'lost' his visual imagery after a heart operation.

"He had vivid imagery previously," recalls Zeman. "He used to get himself to sleep by imagining friends and family. Following the cardiac procedure, he couldn't visualise anything, his dreams became avisual, he said that reading was different because previously he used to enter a visual world and that no longer happened. We were intrigued."

"HE SAID THAT READING WAS DIFFERENT; PREVIOUSLY HE USED TO ENTER A VISUAL WORLD AND THAT NO LONGER HAPPENED"

Zeman searched the literature on visual imagery loss and found there was little out there. "It's weird, it's just a sort of gap," he says. Back in the 1880s, Victorian polymath Francis Galton had published a paper on mental imagery, where he reported that a small number of people couldn't visualise. Since then, researchers have continued to study visual imagery but haven't paid attention to the extreme ends of the visualisation spectrum. Before Zeman started studying it, there wasn't even a name for the experience. Zeman and a classicist friend came up with 'aphantasia', based on Aristotle's term for the 'mind's eye'.

Zeman's assessment of his patient raised more questions than answers. The man could describe a castle, and could say whether grass or a pine tree was darker green, but he reported knowing these answers, not imagining the objects. Functional





brain imaging suggested he couldn't access visual areas when he tried to imagine or remember images.

Zeman's case study about his patient was written about in *Discover* magazine by science journalist Carl Zimmer. Over the next couple of years, 20 people got in touch with Zeman to say they'd read the article and had the same absence of imagery, but they had experienced it for their entire lives. As more was written about the findings, more people got in touch. Zeman now has 12,000 aphantasic volunteers. He estimates that about 2 per cent of the population have little or no visual imagery.

Yet not all experiences of aphantasia are alike. Many people have had aphantasia since birth, but others have acquired it following a brain injury, or sometimes after periods of depression or psychosis. Some individuals don't dream in images, like Zeman's first patient, but others can, even though they are unable to visualise while they're awake.

Brain scanner studies on people have demonstrated a network of brain areas involved in visualisation. These include the primary visual cortex and an area in the fusiform that's close to a region involved in face recognition. The network also includes parts of the frontal and parietal lobes, which are usually involved in decision-making, working memory and attention. Memory areas, including the hippocampus and medial temporal lobe, also seem to be important. As well these specific brain regions, the 'default node network' or 'daydreaming' network is involved. •

HYPERPHANTASIA

Some people's mind's eye is so vivid that the lines between reality and imagination can become blurred...

At the other end of the spectrum to aphantasia is hyperphantasia. People with hyperphantasia describe pictures so vivid that they can find it hard to be sure whether an image was perceived or imagined. Although this sounds pleasurable, it can potentially be confusing, and might make individuals more susceptible to symptoms such as flashbacks in post-traumatic stress disorder (PTSD). "Maybe it's a bit harder to live in the present if you have very vivid visual imagery," says cognitive and behavioural neurologist Prof Adam Zeman. Yet just like with aphantasia, he doesn't think this end of the spectrum has to be problematic. "My feeling is that there are pros and cons to being at either end."

Hyperphantasia is more common than aphantasia, but is still a more extreme experience than most people have. "It's possible to bring to mind strong and clear images of people, places and things," says hyperphantasic artist Clare Dudeney. "It's not always possible to hold them for long in the day because of the distractions of everything else happening around. But at night you can get lost in an imagined world that feels real. Sometimes the only way I can tell it's a dream is when I'm doing something I can't normally do, like fly, or breathe underwater. I used to annoy my husband by getting my sketchbook out on holiday at every incredible scene. Now I've realised that I can relax, take it in and paint it later from memory."

Although she wouldn't change it if she could, sometimes hyperphantasia can be tricky: "When people describe some terrible accident, I visualise it so strongly that I feel it's happening to me," she explains. "I can watch gruesome things on TV and be fine, but a passage in a book can bring to mind such vivid images that I faint."







Dame Gill Morgan recalls her experience of lacking a mind's eye

Dame Gill Morgan realised she saw things differently in her 30s while participating in a management course. The facilitator asked the group to imagine a beautiful sunrise.

"I had no idea what a sunrise looked liked. I know it when I see it, I could explain and describe it, but I couldn't imagine it at all. I thought, 'Everybody's having them on, nobody can see this damn thing." Afterwards, in the bar, she mentioned it to her colleagues: "I said, 'That was daft wasn't it?' And they all went, 'What do you mean? We can imagine...' But I can't. I can't at all."

Until then, she had thought 'the mind's eye' was just an expression. She hadn't realised that people actually could visualise. "I don't think it's been different for me at all," she says. "You'd think I'd be no good at faces or names, but I'm okay. I haven't really noticed it apart from the fact I can't draw. If you said, 'draw a cow', I would have no idea. I know it's got four legs and a head, but I couldn't tell you what was different about the head of a cow compared with the head of a horse. I can't imagine a cow or a horse but I know them when I see them."

She doesn't notice any effect on her ability to empathise or remember; in fact, she thinks her memory may be better in order to compensate. She has had a long, successful career and has a happy family life.

Yet the first time she really missed visualising images was after her parents' death. "Other people, if you talk to them about their parents, they can pull up a picture in their mind's eye. The only way I can do that is to look at a photograph."

These areas are usually active in the resting brain and when we are being introspective. As Zeman says: "If you just chill in a scanner, that's the set of areas that is most active. It turns out to be a kind of daydreaming network, active when you think about the past, or anticipate the future." Zeman thinks it might be involved in visual imagery because when we visualise we are paying attention to internal stimuli instead of the outside world.

"So we know that there's this big network: visual, decision-making, working memory, attention, long-term memory and introspection," summarised Zeman. "Where there's a network, you could predict that it might break down in a number of different ways, which helps to explain why there's more than one sort of aphantasia."

For example, Zeman's initial patient had normal brain activation when he *looked* at faces but couldn't activate these same brain areas when he tried to *imagine* faces. For him, perhaps there was a loss of connectivity between decision-making areas and visual areas. This might have occurred as a consequence of a small stroke during his heart operation. For other people with aphantasia, the neural basis is likely to be different.

DREAM WORLD

What about those people who can dream in pictures but cannot call images to mind when they're awake? Zeman doesn't think this is as odd as it might sound. "What the brain is doing in wakefulness and dreaming are different," he says. Zeman describes dreaming as a 'bottom up' process that's organised from the brainstem, whereas consciously

visualising is a 'top down' process that's driven by the cortex. He thinks this is likely to cause the dissociation between some people's visualisation abilities while dreaming and waking.

But what's going on in the brains of people with lifelong aphantasia? There have not yet been any published studies, but scientists are hoping to have some answers soon. Zeman's team has just finished studying 20 people with high visual imagery, 20 people with no visual imagery and 20 people in the middle, using neuropsychological tests and brain imaging. "So in a few months' time we might have an answer," Zeman says.

Whatever is happening neurally, it does seem to be heritable to some degree, with people with aphantasia more likely to have a close relative (parent, sibling or child) who also struggles to visualise.

One reason aphantasia may have gone nameless and unstudied for so long is because it isn't necessarily a problem. While it makes drawing objects from

imagination impossible, and visualisation strategies cannot be used for memorising, there are other ways to mentally represent information. Some people use words or symbols, others report having a good 'mind's ear' or 'mind's nose' instead of a 'mind's eye', or say that they have kinaesthetic (movement-based) imagery.

While there are individuals with aphantasia who report memory difficulties, this is not true for everyone. There is a trend for people with aphantasia

"IT'S PERFECTLY
POSSIBLE TO BE
CREATIVE AND
IMAGINATIVE
WITHOUT
VISUALISATION"

to work in academic and computer-related careers, and for those at the other end of the spectrum to work creatively. But there are exceptions. There are aphantasic artists, who either depict objects they

> see, or use images they make on the paper as a stimulus to engage with. "It's perfectly possible to be creative and imaginative without visualisation," says Zeman.

> Zeman doesn't think aphantasia needs diagnosis and treatment. "It's an intriguing variation in human experience, not a disorder," he says. Indeed, the scientist Craig Venter, the first person to decode the human genome, has described his aphantasia as useful in helping him to concentrate on scientific problems.

The presence of a large and previously hidden aphantasic community reveals how it is possible for all of us to be seeing the world differently without even realising. Brain imaging can help us understand neurodiversity of all sorts, but we'll only know there's difference to be investigated if we don't assume that you see what I see,

and instead we ask curious questions. •

Dr Lucy Maddox is a clinical psychologist, lecturer and writer.

DISCOVER MORE

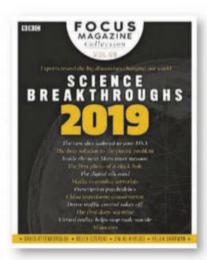
From January 2019 there will be an exhibition of art by people with aphantasia and hyperphantasia, held at Glasgow University and then Exeter University. For more



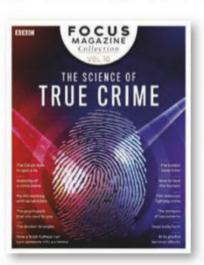
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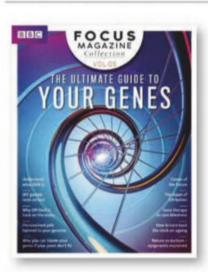
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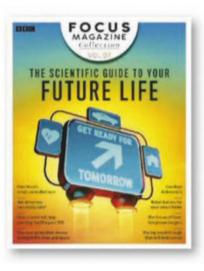
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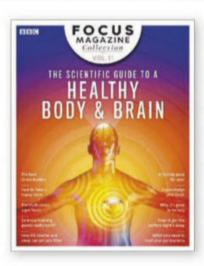
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PHYSICS THEORY OF THE ORIGIN OF



Move over, biology. There's a new theory about how life first emerged from the primordial goo, with physics enjoying a starring role

WORDS: BRIAN CLEGG



like behaviours could emerge from

an inert collection of chemicals.

"I was always interested in how the physics of big, messy assemblies of particles becomes lifelike, ever since I was doing research on protein folding as an undergraduate," England says. "It was the way I could successfully refuse to choose between theoretical physics and biology, which both were fascinating to me."

England's work is based on the well-established physics of thermodynamics — the science that describes how heat moves from place to place and is crucial for many natural processes. He calls his theory 'dissipative adaptation', as it aims to describe how structures emerge and change through the dissipation of energy, primarily heat, into their environment. This process increases the entropy (the amount of disorder) in the surroundings, which Austrian quantum physicist Erwin Schrödinger identified as necessary for living organisms to function. Crucially, the increase in entropy makes it possible for the evolving structures to stay in what is known as a 'non-equilibrium state'.

Usually a system (which could mean anything from a box of gas to a complex structure) comes into equilibrium with its environment. This means that there is no net flow of heat between the system and its surroundings. For example, if you leave a cup of hot tea on the table, it will eventually reach the same temperature as the room, much



"I was interested in how the physics of big, messy assemblies of particles becomes life-like"

ABOVE: Could physics explain how life emerged on early Earth?

to the chagrin of the tea-lover who was looking forward to a cuppa. But living things are in a non-equilibrium state, taking energy from sources such as sunlight and food and pushing that energy out — 'dissipating' it — into their surroundings. This enables a living organism to reduce its own entropy, so it can grow and build structure. And it is the physics of such non-equilibrium states that England and his team investigate, by using computer simulations to look for situations where life-like behaviours emerge spontaneously.

BEYOND BIOLOGY

This is not the first time that a physicist has attempted to take on the deeper questions of biology. In 1944, Schrödinger published a book



based on a series of lectures he had given in his adopted home of Dublin. The book, *What Is Life?*, emphasised the central significance of energy flows and entropy. In the book, he also suggested that biological inheritance would depend on what he called an 'aperiodic crystal' – a molecule that could carry information in its structure – a prediction that was fulfilled with the discovery of the structure of DNA.

"The beginning point of my current line of research – which really has veered away from biology, at this point – was realising that to think about the physics, you have to take what's interesting about life and break it into separate well-defined physical phenomena that you can then talk about in terms of thermodynamics. So, for example, living things make copies of themselves but not all self-replicators are alive," says England.

The behaviours that England is targeting include reproduction, harvesting energy, natural selection and the ability to anticipate the future. Sometimes these effects can be seen in simple, familiar phenomena that bear no resemblance whatsoever to life, such as snowflakes and sand dunes, he says. But in both cases, these structures are able to form as a result of releasing energy into the surroundings. "In the case of a snowflake, it's the •

WHAT IS ENTROPY?

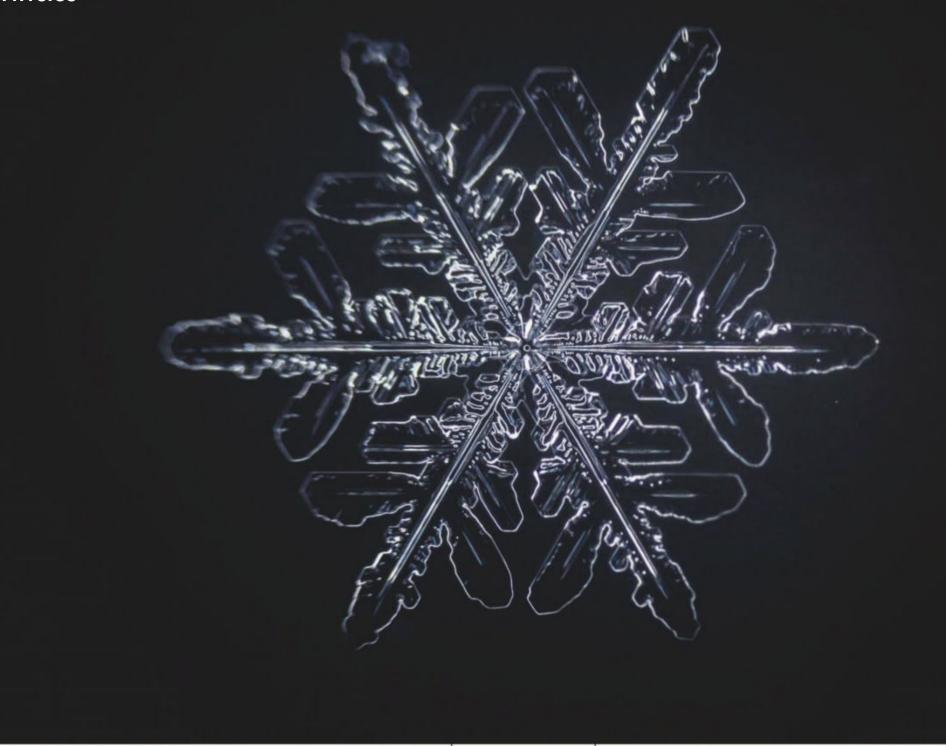
The second law of thermodynamics sounds trivial when it's described in simple terms as 'heat moves from a hotter body to a colder body' – but there is much more going on behind this simple statement than may first appear. The second law is involved in everything from life to the ultimate fate of the Universe.

An alternative, more technical description of the second law is that 'in a closed system, entropy stays the same or increases'. Entropy is a mathematical measure of the amount of disorder in something, based on the number of different ways that you can rearrange the components parts of the object you are considering. Broadly speaking, the more disordered a system is, the higher its entropy. Take *BBC Focus* magazine. There's just one way to arrange the letters and images to make the magazine you're reading. There are also vast numbers of other ways the same letters and images could be laid out but they would be scrambled up and not make sense. We can say then that the magazine has lower entropy than a scrambled version.

The second law also tells us that over time entropy will increase – everything runs down and decays. Such an increase in entropy explains why it's much easier to break a glass than unbreak it – going from the single arrangement in the glass to the many possible arrangements of the bits of the glass. Similarly, it's far easier to mix milk into your coffee than to separate it out, going from having the coffee molecules in one place and the milk in another to the many possible ways those molecules can be mixed together.

With this in mind it may seem impossible, or at least highly unlikely, that living organisms could ever have developed as they have far more order than the random mix of the atoms making them up. This is where the 'closed system' bit of the law comes in. If you put energy into a system from the outside it's perfectly possible to reduce entropy within it, because the entropy of the energy source and the 'closed system' combined will still increase overall.





• heat released by the exothermic [heat-emitting] crystallisation of liquid water into solid ice," he says. "In the case of a sand dune, the flowing air gets the sand grains moving, but then they stop again because they rattle against each other and lose that energy as heat to the surrounding air."

ENTROPY AND EVOLUTION

The evolutionary history of an organism is stored in its DNA, moulding its current form. England believes that an organism's history of dissipating heat and therefore increasing entropy also help shape its structure. Without DNA to act as a record of changes, England believes that the physical form of the structures can hold information.

"Think about a glass being sung at by an opera singer, and it resonates and violently changes its shape and shatters. Once it shatters, it is much worse at absorbing energy from the song, as it is a pile of shards. It changes its shape much less, it has become much more stable," he says. "But those shards are not a random arrangement of glass, they contain a lot of information about the shape the glass was in when it shattered. So even though they are bad at absorbing energy, they

ABOVE:
Snowflakes are
complicated,
forming due to
liquid water
crystallising into
ice, but they are
not alive

have a signature of a moment in history when the opposite was the case, which can be reconstructed with the right detective work."

Sometimes, in the team's simulations, a surprising level of self-organisation emerges. For example, when they begin with a virtual soup of different simulated chemicals interacting, some start to take over at the expense of others. They then begin to dominate as they prove better at harvesting the available energy.

"There are lots of things we think of life being distinctively good at, for example energy harvesting, predictive computation [anticipating the future] and self-repair, that we may be able to get to self-organise even in the absence of Darwinian evolution by self-replication and natural selection," England says.

Though still in the early stages, the theory is not without its critics, and England himself agrees that there is a huge gap between simply observing life-like behaviour and life itself.

"All life we see is the product of countless competing of past generations of things that were already alive and got to co-evolve for a long time," he says. "Also, any living thing is a composite of

"We may be able to get to self-organise even in the absence of ... evolution"

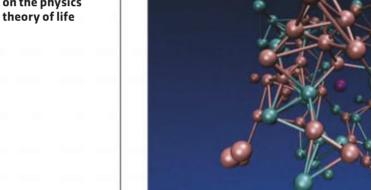
many distinctively life-like behaviours, and they do not necessarily all come hand-in-hand at the outset. For example, something could be a very good energy harvester and not necessarily be in any way capable of self-replication, and I do not claim to know anything about how the package deal we call life first gets bundled together."

What he does believe, however, is that his team's work is enriching what he calls the "starting toolbox" for life to form. For the moment, their work is purely based on computer simulations, though other researchers are starting to take up the idea and work on investigating similar thermodynamic effects in physical experiments.

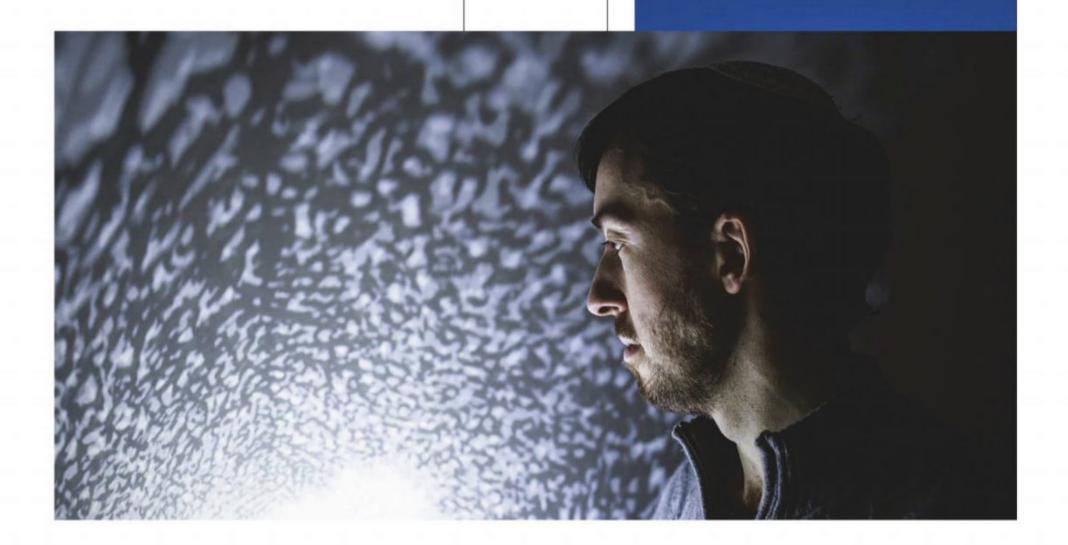
We may not have the answer to how life began yet, but dissipative adaptation gives us a clearer picture of one of the fundamental principles that has encouraged the emergence of living things. • computer simulation by The turquoise particles are being driven by an oscillating force, which leads to bonds forming over time

BELOW: MIT's Jeremy England, who is working on the physics

RIGHT: This Jeremy England shows particles in a gooey fluid.



Brian Clegg is a science writer who has written more than 30 science books. His latest is The Graphene Revolution (£8.99, Icon Books)



WHY ARE GIRLS PUT OFF SCIENCE?

Many girls are not choosing to study science, technology, engineering and mathematics at A-level and university. We wanted to find out why certain subjects get a thumbs-down...

WORDS: ALICE LIPSCOMBE-SOUTHWELL

round 40,000 jobs in STEM – that's science, technology, engineering and maths – are left vacant in the UK each year. To make matters worse, women in science-based jobs are leaving, frustrated with sexism, bias and the lack of opportunities for progression.

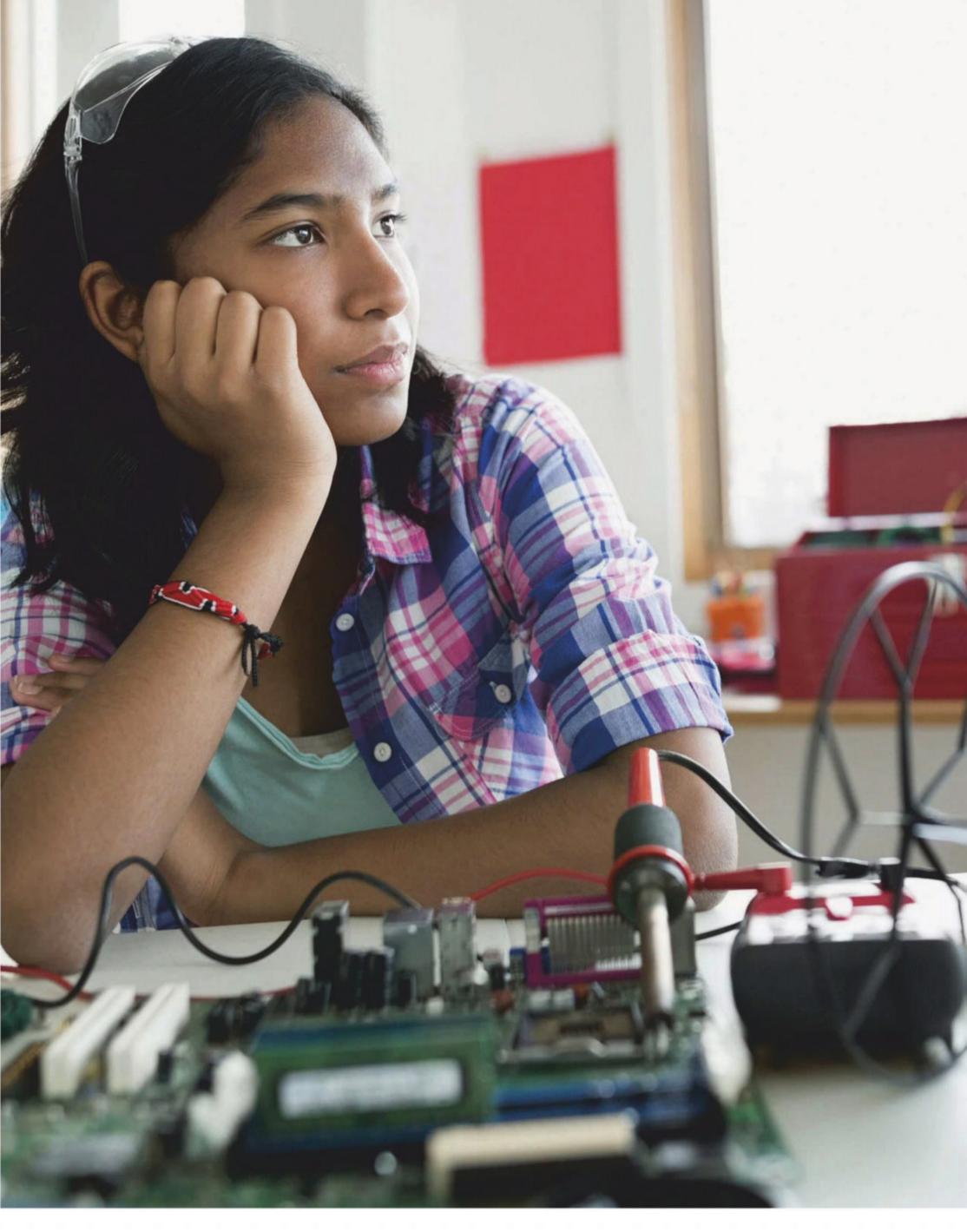
It's going to be difficult to replace these women in the years to come because fewer girls than boys are studying core sciences at schools, colleges and universities. At A-level, just 19 per cent of girls choose two STEM subjects, compared to 33 per cent of boys. Maths and physics fare particularly poorly: last year 59,270 boys took A-level maths, compared to 38,357 girls; and 29,422 boys took physics, compared to 8,384 girls.

On the eve of International Women in Science Day on 11 February, we wanted find out exactly what it is that's putting girls off studying some of these subjects, and what can be done to stop them turning away.

We surveyed around 100 readers of *Girl Talk*, a magazine with a readership of girls aged 7 to 11, to find out what they think about their science lessons. We also sent out surveys to over 1,000 11- to 14-year-olds to find out about their most and least favourite school subjects, their heroes and their career aspirations. Finally, we sent questionnaires to nearly 2,000 adults asking them to look back at the careers advice they received at school.

The results were revealing. When we asked the 11- to 14-yearolds to pick their favourite three subjects, we found a marked difference between the genders: for the girls, art came





out on top, with English and drama joint second. For the boys, information and communication technology (ICT)/computing nabbed the top spot, with PE and maths coming in close behind. When we asked the interviewees why these subjects were their favourites, 38 per cent of girls (compared to 28 per cent of boys) responded with 'I like the teacher'. Previous research carried out by the Institute of Physics has shown the enormous importance of teachers for girls' aspirations. "Girls have learnt to be more cautious," says Beth Bramley, gender balance manager at the Institute of Physics. "Girls respond better to being encouraged, teachers having belief in them and showing enthusiasm for the subject – more so than the gender of their teacher."

THE TURNING POINT

Yet at a younger age, the girls we surveyed really enjoyed science, especially the experiments, so there's something happening around the time girls are entering secondary school that's turning them off the subject. According to Bramley, they could be getting sidelined when it comes doing the fun stuff. "With science experiments, if you let young

"Girls respond better to being encouraged, teachers having belief in them and showing enthusiasm for the subject"

people have free rein, then the boys get to do the hands-on experiment, and the girls take a step back and write stuff up," she says. But she says there are quick ways to fix this problem. In group work, teachers can assign the students particular roles, for example one student might be a scribe and another one might be in charge of a particular piece of apparatus. These roles can then be rotated for each lesson, so that everyone has an opportunity to do everything. There is evidence that once that girl has had a hands-on, leadership role a couple of times, she becomes more confident in carrying out the tasks it involves.

And that confidence is a key part of encouraging more girls into the sciences. Due to unconscious bias, sexism and various gender stereotypes, girls are more likely than boys to think that they aren't

> good enough to pursue subjects such as maths and physics to A-level, seeing them as only for the super-smart. "There is [also] the stereotype threat of who will be in that class," says Bramley. "If you've done very well in physics, you've usually done very well in English, French and history. And maybe all your friends are doing history and French, so it's those moments, where even if you've achieved [the necessary good grades], you don't see yourself as being on a pathway that could lead to you becoming a scientist."

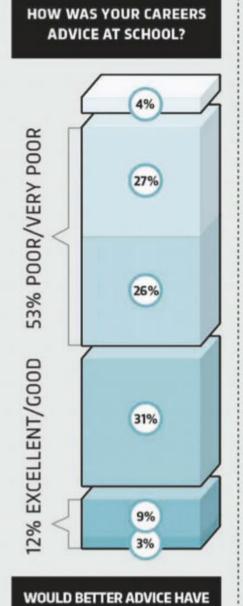
At a time when hormones are raging, tempers are volatile and friendship groups are fickle, it can be hard for youngsters to make tough decisions about which subjects to choose. In fact, there's a growing body of research that shows teenage brains are different from adult brains. "Different parts of the brain develop at •

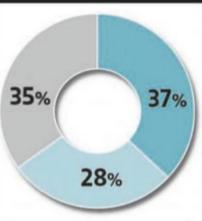
The gender of a science teacher is less important than the encouragement they give their students



OUR SURVEY RESULTS FIND OUT MORE AT: SCIENCEFOCUS.COM/ GIRLSINSCIENCE

ADULTS

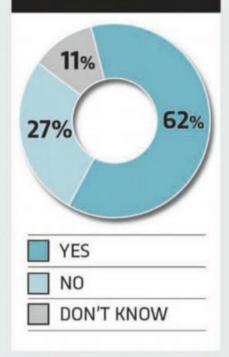




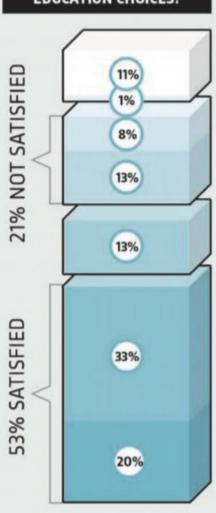
CHANGED YOUR CAREER PATH?



DID YOU RECEIVE CAREERS ADVICE?



HOW SATISFIED ARE YOU WITH YOUR FURTHER **EDUCATION CHOICES?**



KIDS

	GIRLS
т	BOYS

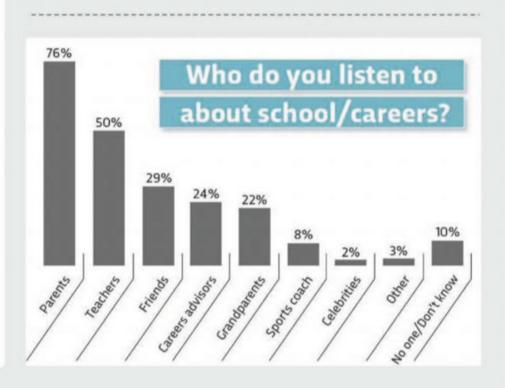
WHAT ARE YOUR **FAVOURITE SUBJECTS?**

Art	43%
English Language/Literature	28%
Drama	28%
Maths/Statistics	26%
ICT/Computing	24%
History	23%
PE (physical education)	22%
Music	22%
NOTHING/DON'T KNOW -	- 2%
ICT/Computing	41%
PE (physical education)	36%
Maths/Statistics	35%
Design and Technology	29%
Art	24%
History	23%
English Language/Literature	21%
Music	16%
NOTHING/DON'T KNOW -	- 1%

WHAT DO YOU WANT TO BE WHEN YOU GROW UP?

DON'T KNOW YET —	18%
Computer programmer	3%
Graphic designer	4%
Dancer	4%
Fashion designer	4%
Blogger/vlogger	4%
A vet	7%
Doctor/nurse/dentist	7%
Teacher	8%

Computer programmer	10%
Engineer	8%
Blogger/vlogger	6%
Business owner	4%
Chef	4%
Author	3%
Scientist	3%
Doctor/nurse/dentist	3%





• different rates, and during adolescence the parts of the brain relating to social reward are more highly developed than the parts of the brain involved in problem-solving, planning and decision-making," says clinical psychologist Dr Lucy Maddox.

This makes sense. Teenagers are keen to fit in and no one wants to be called a swot, so there may be a temptation to take subjects that have an 'easier' reputation. Perhaps they might fare better if we allowed them to keep their options open for longer, by letting them study a broader range of subjects. Especially if their brains aren't quite ready to be making choices that will affect the rest of their lives.

CAREERS ADVICE

Yet despite teenagers' keenness for independence, they are not averse to asking for advice: three-quarters of our respondents told us they listened to their parents' guidance about school and careers, and half said they paid attention to teachers. While it's encouraging that they are willing to listen to input from adults, it also means that when a careers advisor tells you that your ideal job would be as a bricklayer, that advice – even if well-intentioned – could lead you down a path that you end up regretting in later life. Case in point: BBC Focus editor Daniel Bennett was told that he should be a landscape gardener... readers of this magazine will be relieved to hear he didn't follow that advice, as his skill set is better matched to editing than gardening (although I have been impressed with his ability to keep the pot plant on his desk alive for the last six months).

Speaking of careers, the top choices among 11- to 14-year-old girls were teacher, medical roles and vet/zookeeper. This fits in with research from the Campaign for Science and Engineering, which found that parents were keen for their daughters to be teachers, doctors and nurses, but wanted their sons to be engineers, scientists and tradesmen.

Yet even if the girls genuinely did want to follow those career paths, then favourite subjects of art, English and drama would not be as useful as core STEM subjects in helping them reach those goals. Something here doesn't add up. Certainly, when we interviewed the adults, over half said their careers advice at school had been poor, with just 12 per cent rating it as good. Around one in five respondents said they were not satisfied with the further education choice they made, while more

ABOVE: Dr Jess Wade (centre) campaigns to get more women into STEM roles

"The most exciting and successful scientific research happens when people from different disciplines, with different backgrounds, from different parts of the world work together"



BELOW: It can be helpful to introduce students to a range of role models – like NASA mathematician Katherine Johnson – rather than always showing stereotypical male scientists



than one-third agreed that better advice would have altered the career path they followed. That's an enormous number of adults who are going to work every day, feeling dissatisfied, and watching the minutes tick slowly by until they can go home.

But is careers advice better today? That's up for debate. In 2015, the UK government set up the Careers & Enterprise Company (CEC) in order to help pupils achieve their career goals. Then in December 2017, a new government careers strategy was unveiled that said schools needed to meet a gold standard of eight 'Gatsby benchmarks', to provide the best careers provision in schools and colleges, which the CEC would help schools achieve. Those benchmarks are: a stable careers programme; learning from career and labour market information; addressing the needs of each pupil; linking curriculum learning to careers; encounters with employers and employees; experiences of workplaces; encounters with further and higher education; personal guidance. Yet according to the CEC's 2018 report, on average schools are achieving just two of the eight benchmarks, and 18 per cent of schools are not achieving any at all.

BETTER FUTURE

It's not all bad news, though. Recently, a study called The Drayson Pilot, spearheaded by the Institute of Physics, combined three strands of research to see if girls' experiences of physics could be improved. The first strand worked on girls' confidence, introducing them to extracurricular clubs and external speakers. The second strand looked at inclusive teaching and unconscious bias, and showed students a wide

range of physicists. It also introduced students to the relevance of physics for future career paths. The third strand was a whole school approach, involving teachers and parents. By bringing those three stands together across six schools over two years, the number of girls taking AS-level physics more than trebled.

"It shows that schools do have a role to play and can do something positive," says Bramley. "Projects like this show that where there are structures in place, they can have a massive impact on the choices young people are making."

The positive news doesn't end there though. The Gender Action Award, a gender equality accolade for schools, has recently been launched by King's College London, University College London, the Council of Modern Languages and the Institute of Physics. It takes a look at culture change in schools designed to tackle gender stereotyping and bias, and asks schools to upload evidence so they can be assessed and awarded accordingly. It has received funding from the Mayor of London and this year will be rolled out to primary and secondary schools in the capital. A national rollout is planned for 2020. This takes us one step closer to a world in which youngsters are free to choose the subjects and careers they wish, without having to worry about the burden of gender expectations.

"Whether it's materials, ecosystems or our bodies, science is about asking questions of the world around us—and we need as many voices as possible pushing the limits of our understanding," says campaigner and physicist Dr Jess Wade. "The most exciting and successful scientific research happens when people from different disciplines, with different backgrounds, from different parts of the world work together. If we want science to benefit the whole of society, everyone needs to be able to contribute to the discussion."

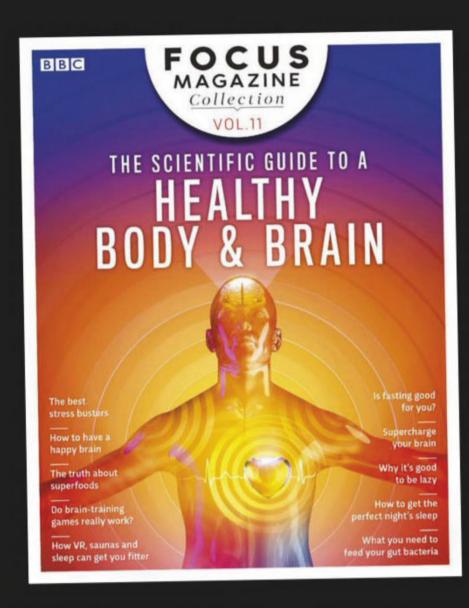
Alice Lipscombe-Southwell is the production editor at *BBC Focus* magazine.

DISCOVER MORE

Listen to a panel discussion with four eminent women scientists at sciencefocus.com/science/why-arent-there-more-women-in-science

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YOUR QUESTIONS ANSWERED

FEBRUARY 2019 EDITED BY JAMES LLOYD





What makes someone objectively beautiful?

SHEIKH HUSSAI, LOUGHTON

Psychologists have found that faces we rate as attractive tend to be highly symmetrical, and the positioning of their features – such as the distance between the eyes – tends to be very 'average' (that is, it reflects the average of all the different configurations seen in the wider population). Even tiny babies prefer to look at average and symmetrical faces, which suggests an innate preference. It's not known for sure why we're attracted to these kinds of faces, but two theories are that facial symmetry somehow signals good health, and that average faces are attractive because they feel familiar. \mathbf{c}

What happens to toilet paper?

NINA PERKINS, KNUTSFORD

Toilet paper is made from short cellulose fibres, which is why it tears so easily. In water, those fibres quickly come untangled and form a thin sludge that's easily carried by the water flow in the sewage system. By the time it reaches the sewage treatment plant, most of the toilet paper has completely disintegrated, and goes straight to the sludge digester tanks to be broken down into compost, along with the actual poop. Anything more robust than toilet paper, such as flushable wipes, doesn't break down, though, and has to be removed using a system of mesh filters, before going for landfill or incineration. LV



...I FALL IN LOVE?

Love is mostly a biological trick that evolution plays on you to encourage you to reproduce effectively. Those memories of your fantastic first date that are burned forever into your brain? You can blame that on the extra proteins in your bloodstream that encourage new neuron connections in your brain when you're in love. But that's not all...



1. You feel happier

Your brain releases more of the hormones dopamine and oxytocin. These feel-good chemicals give a euphoria similar to the effects of cocaine.



2. You're possessive

Another hormone produced by the loved-up brain is vasopressin. Studies in animals show that this chemical increases the sense of attachment and territoriality.



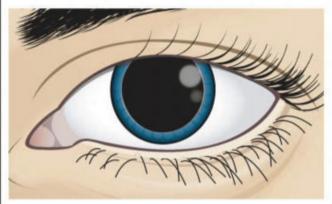
3. One-track mind

Elevated levels of adrenaline and norepinephrine hormones, coupled with lower serotonin, make you anxious and can cause a sensation of obsessive focus on your love interest.



4. Jangling nerves.

Adrenaline and norepinephrine also cause more physical symptoms of stress around your crush, including sweaty palms, a fluttering heart and a dry mouth.



5. Wide eyes

The autonomic nervous system – which regulates the body's unconscious actions – is deeply connected to the arousal centres of your brain. When you see someone attractive, your pupils automatically dilate.



6. You feel less pain

A 2010 study at Stanford University found that staring at a photo of someone you're deeply in love with reduces moderate pain by 40 per cent.



Is there any chemical difference between women's and men's antiperspirant?

GAVIN RHYS, CARDIFF

No, they just have different fragrances – and packaging. The chemicals that do the hard work are generally the same. Deodorants target bacteria with antibacterials, while antiperspirants reduce sweat levels with aluminium- or zirconium-based chemicals. These react with sweat to form polymer plugs that prevent perspiration escaping from sweat glands. Body odour develops when bacteria on our skin start to break down sweat using enzymes. According to Swiss research, bacteria feasting on male sweat produce higher levels of a cheesy, rancid chemical called 3-hydroxy-3-methylhexanoic acid (HMHA). Meanwhile, female sweat provides more of the sulphurrich 3-methyl-3-sulfanylhexan-1-ol (MSH) chemical, reminiscent of onions and tropical fruit. ED

IN NUMBERS

8cm/sec

The recorded speed of a tawny nurse shark foetus as it swam from one uterus to another (sharks have two uteruses).



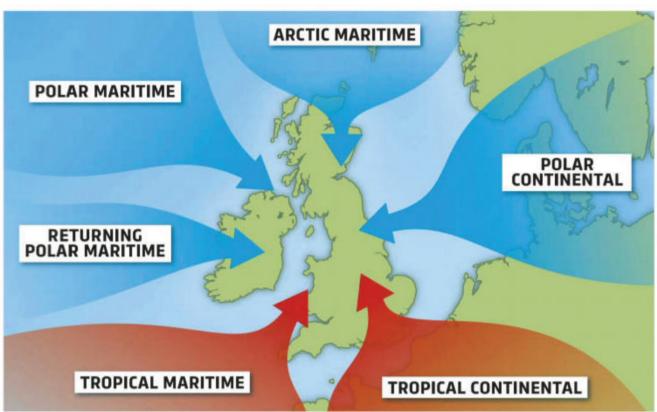
The age, in months, that babies need to be before they can recognise faces in profile view.

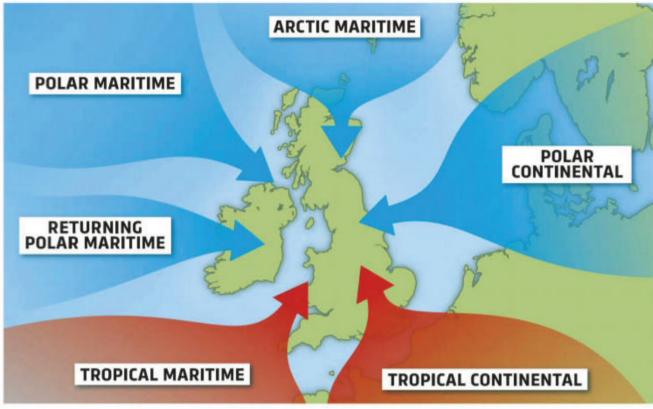


Why do the British talk about the weather so much?

JULES WEAVER, VIA EMAIL

Brits really do like to talk about the weather: over 90 per cent admit to having done so in the previous six hours. But there's always plenty to talk about, because our location means our weather is affected by six different air masses. Southwesterly winds expose us to warm, moist tropical air from the Atlantic (tropical maritime), bringing rain and mild conditions, while Arctic air masses from the north (Arctic maritime) and northwest (polar maritime) can deliver cold, wet weather and potential blizzards in winter. Another air mass from the Arctic, travelling via the North Atlantic (returning polar maritime), delivers mild, cloudy weather. Meanwhile, our summers can sizzle under the influence of hot, dry air from North Africa (tropical continental) or eastern air flows from the continent (polar continental) – which can also cause winter temperatures to plunge. Small wonder forecasting is so hard! RM

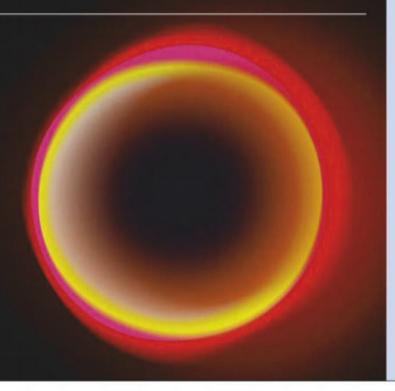




If nothing can escape from a singularity, how did the Universe manage it?

KEITH MAYES, NORFOLK

Einstein's theory of gravity predicts that the Universe began in a singularity – a state of zero size and thus infinite density and gravitational force, which would prevent it expanding. But theorists believe that such a state - also predicted to exist inside black holes – is the result of his celebrated theory ignoring quantum effects. These would prevent a truly point-like singularity from forming, eliminating the infinitely strong gravity, and thus allowing the Universe to expand. RM



What's the difference between a shoal, a school and a pod?

HANNAH McBRIDE, SOUTHEND

When fish, shrimp or other aquatic creatures swim together in a loose cluster, this is typically called a shoal. It can be a mix of different species. A school is a group of the same fish species swimming together in synchrony; turning, twisting and forming sweeping, glinting shapes in the water. Fish probably do this to confuse predators and to save energy (by using the 'slipstreams' of other fish). Pods are herds of marine mammals including whales, dolphins, walruses and seals. HS







How did we decide how heavy a gram was?

TOBY GRAHAM, SHREWSBURY

For over 200 years, the kilogram has been the international standard unit of mass. Yet its name suggests there was once another standard, which was 1,000 times lighter: the gram. Chosen by a panel of distinguished French academics in 1791, this was originally defined as the mass of one cubic centimetre of distilled water at 4°C. This is the temperature at which water reaches its maximum density, thus giving a cubic centimetre of the stuff its greatest possible mass. While scientifically neat and tidy, the mass of a gram was still pretty small – barely as much as an almond - and it was quickly criticised as impractical for commercial use. So in 1799, the French republic adopted the kilogram, defined via the mass of a platinum weight – the approach still used until last year, when it was finally replaced by a far more sophisticated definition. RM

Is there any point turning my phone to 'flight mode' on a plane?

JO ADAMSON, BATH



Until recently, concern that electronic emissions from laptops, e-readers and phones could interfere with aircraft systems led to passengers being asked to put such devices into low-emission 'flight mode' during take-off and landing. In recent years, these restrictions have been eased, but they still apply to phones. That's because the aerospace industry believes that radio emissions from phones still have the potential to cause interference – and are suspected to have sometimes affected headphones used by pilots. RM



WHO REALLY DISCOVERED?

OXYGEN?







JOSEPH PRIESTLEY

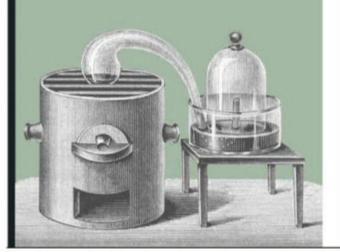
ANTOINE LAVOISIER

CARL SCHEELE

Over 500 years ago, Leonardo da Vinci suggested that the air we breathe contains something vital to life, having found that combustion seemed to remove it from air, causing animals to suffocate. Many medieval alchemists tried to find it, without success. Then in 1774, the English chemist Joseph Priestley succeeded in both separating out the substance, and showing it was a single chemical element, rather than some special mix of gases. Priestley was also the first to publish his findings and thus allow others to confirm his discovery - a process which is still regarded as vital in claiming priority in discovery disputes.

The French chemist Antoine Lavoisier later claimed to have discovered the gas independently of Priestley. He named it oxygen (meaning 'acid maker'), and investigated its properties. However, it's known that Priestley had already shown Lavoisier how to make oxygen, undermining his claim.

Some historians argue that credit for discovering oxygen should go to the Swedish chemist Carl Scheele, who identified it several years before Priestley. Unfortunately, a letter he sent to Lavoisier describing his work never arrived, while his scientific report sat in a printer's office for two years, ensuring his work was overshadowed by Priestley and Lavoisier. RM



When you pull out a grey hair, will it grow back to be grey?

ALICE WANG, EPPING

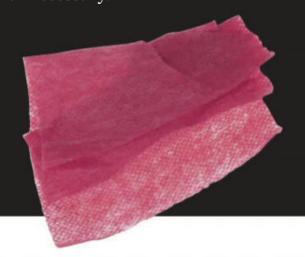
Yes. Hair colour comes from pigment cells in the follicle, which add pigment to the hair shaft as it emerges. As we grow older, the follicles gradually produce less pigment and, eventually, stop colouring the hair at all. Plucking a grey hair doesn't revitalise the pigment cells, so the next hair to emerge from that follicle will also be grey. IV



How do the colourabsorbing sheets used in washing machines work?

ROGER BRITTON, VIA EMAIL

Many fabric dyes are acids that form negatively charged molecules in water. The colour-absorbing sheets used in your laundry contain positively charged compounds that attract any dye molecules that leach out of coloured clothes. Once the compounds have grabbed a dye molecule, a chemical bond forms that binds the dye to the sheet, so it won't bleed out onto the laundry again. So the science behind it is sound, but modern dyes are much more colourfast than they used to be, so colourabsorbing sheets are often unnecessary. LV



Do any foods help to decrease anxiety?

LAURA PAJUODYTE, LONDON



Marmite lovers, rejoice. Thanks to its high levels of B vitamins, the yeast-based spread may ease anxiety, according to a recent study at Victoria University in Australia. Vitamin B12, for example, is thought to be linked to the production of serotonin – a chemical in the body that helps to regulate mood. For the Marmite haters out there, a recent Taiwanese study suggests that omega-3 fatty acids, found in foods such as oily fish and nuts, may also help to relieve anxiety. ED

GETTY IMAGES X5, SHUTTERSTOCK, ALAMY, NATUREPL.COM ILLUSTRATION: PETER SUCHESK



CROWDSCIENCE

WHY DO WOMEN LIVE LONGER THAN MEN?

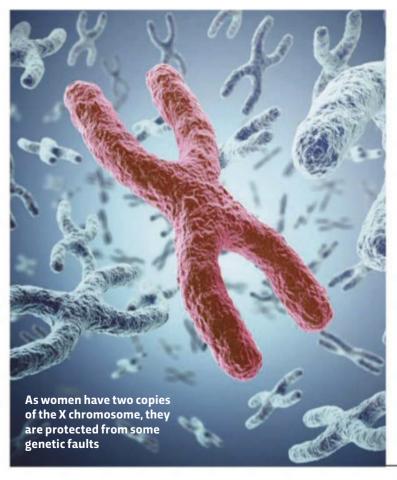
We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at **www.bbcworldservice.com/crowdscience**

What causes the differences?

In every country in the world, women live longer than men. In the UK, women get an extra four years on average; in Russia it's an extra 11 years (the highest in the world). Some of these differences in life expectancy are down to lifestyle factors, but there's something much deeper encoded in our genes. Women have two copies of the X chromosome in every cell, whereas men have one X and one Y chromosome. With women, if one of the genes on the X chromosome becomes faulty, they have a healthy 'backup' copy. Men, on the other hand, have to make do with any faulty genes on their single X chromosome, which can put them at a greater risk of disease.

When do the differences begin?

From the moment they are a ball of cells, males are more vulnerable than females, with male babies at a 20 per cent greater risk of dying in the womb. But according to ageing expert Prof David Gems at University College London, mortality in men soars once puberty hits. Some of this is due to men's more risky behaviour, but studies suggest that long-term problems are caused by the physical changes in the body created by the hormone testosterone. A 2012 study of records from pre-19th-Century Korea showed that eunuchs who were castrated as boys before the testosterone surge of puberty, lived 14 to 19 years longer than their contemporaries.





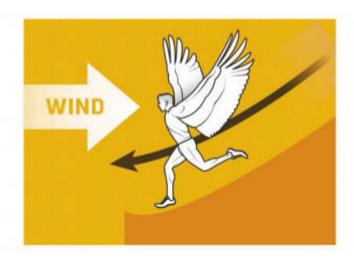
Will men ever catch up with women?

With the life expectancy differences so tied up with hormones and genetics, it seems unlikely that men will ever close the gap entirely. But the good news is that not all of our ageing is predetermined. The Russian gap between the sexes, for instance, is thought to be due to the culture of heavy drinking and smoking. As cultures can change, it's possible for both sexes to live healthier lives with the genetic hand they are dealt. Meanwhile, advances in our treatment of diseases should help us to close the gap even further.



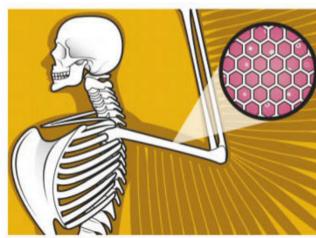
Marnie Chesterton is the presenter of Why Do Women Live Longer Than Men? – an episode of CrowdScience that can be streamed at bbc.co.uk/sounds/play/w3cswvxm

WHAT WOULD HAPPEN IF...HUMANS GREW WINGS?



1. WINGS

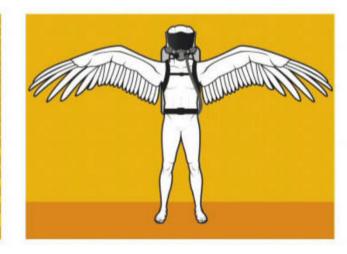
The heaviest-ever flying bird was Argentavis magnificens, which lived six million years ago. It had a similar height and weight to an adult human, with a wingspan of six metres. These wings would have been too large and hefty for continuous flapping, so it probably flew more like a glider, taking off by running downhill into a headwind. We'd have to adopt a similar flying style.



2. MUSCLES AND BONES

To flap these wings, we would need pectoral muscles twice the size of a pro bodybuilder's.

Our bones would be lighter and therefore weaker, so we'd need to strengthen our collarbone by fusing the clavicles into a wishbone. We'd also need a 'keel' bone protruding down the centre of our chest, to allow the pectoral muscles to attach further from the shoulder, increasing their leverage.



3. TECHNOLOGY

Even with all this, we probably couldn't fly unaided. Birds have a more efficient one-way airflow through their lungs to get more air with each breath, and their muscles have extra oxygen-carrying proteins. Their nervous system runs faster to give them the reaction times needed for in-flight manoeuvring. We would need help from an oxygen cylinder, and a flight computer with a heads-up display.



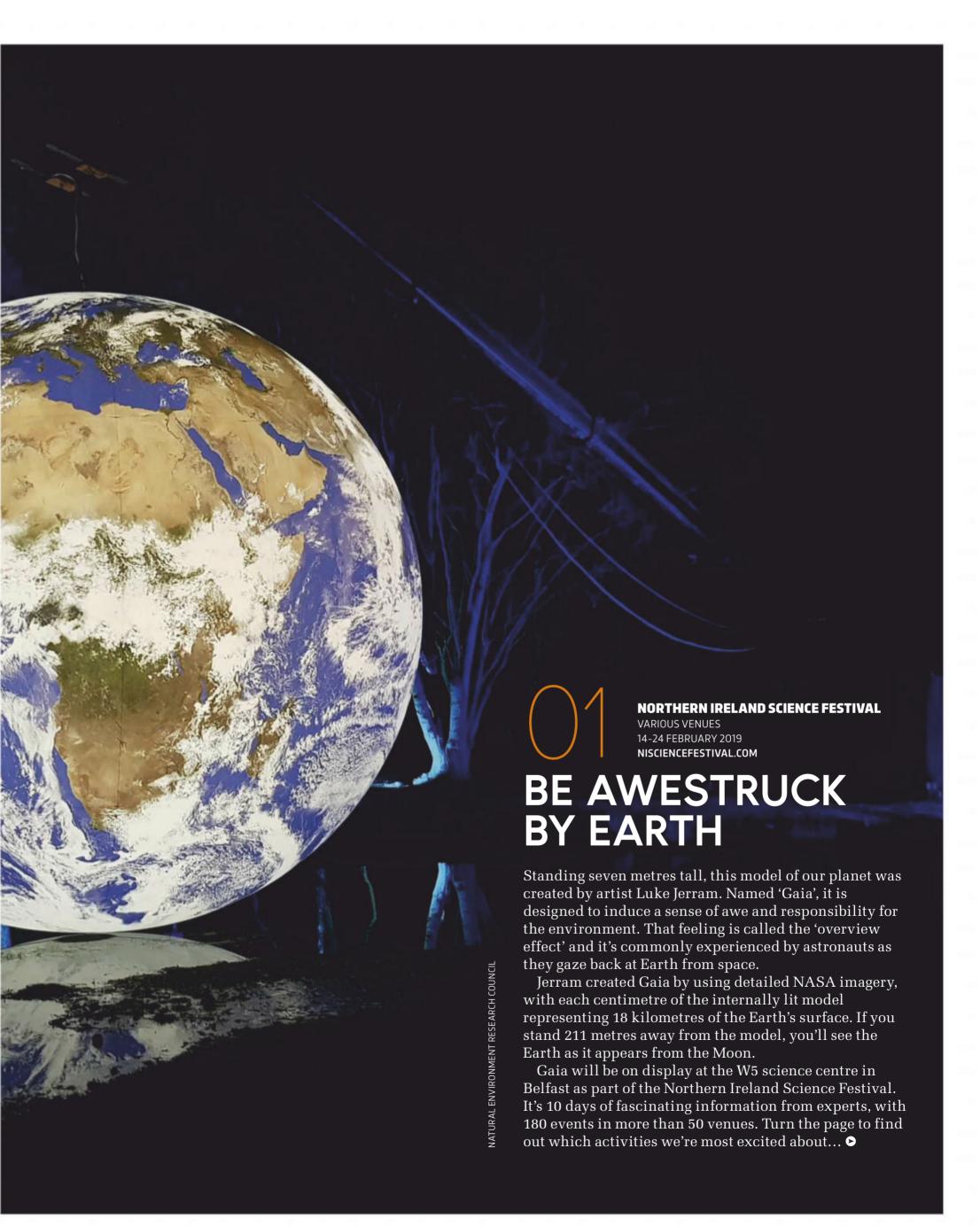
OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

FEBRUARY 2019

EDITED BY HELEN GLENNY





LEO BOYD/JAMES LYTTLE, ESO/MARTIN KORNMESSER, GETTY IMAGES, TONY BARTHOLOMEW, BAPS LONDON

WHAT TO ENJOY IN BELFAST...



NEUROMUSICOLOGY

THE BLACK BOX, BELFAST 17 FEBRUARY 2019, 4PM

Join cognitive neuroscientist Dr Niamh Kennedy to explore the neuroscience of music, and find out how the brain controls movement. Kennedy will be helped by harpist Ursula Burns, who'll be having her brain activity imaged live while she plays the piano and the harp at the same time.

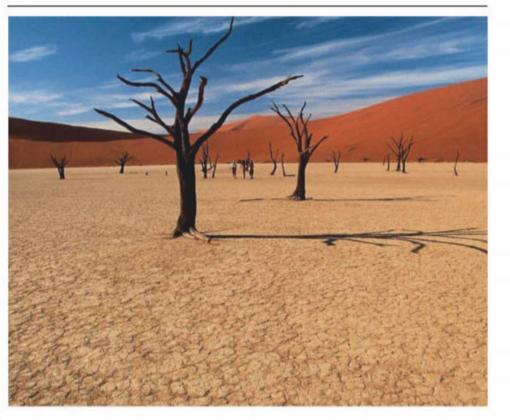


MENSA MAGNIFICENT MONDAY QUIZ

THE BLACK BOX, BELFAST 18 FEBRUARY 2019, 7.30PM

Leave the movie soundtracks and obscure sports facts behind. This team quiz is focused on the good stuff: science, technology and engineering. It's light-hearted, so don't worry if your quizzing skills aren't at MENSA level – it's all about the craic.





WILD WEATHER, PHYSICS & CLIMATE CHANGE (OR 12 YEARS TO SAVE THE WORLD)

QUEEN'S UNIVERSITY BELFAST 24 FEBRUARY 2019, 1PM

According to IPCC's climate report published in 2018, we now have just 12 years to prevent dangerous destabilisation of the Earth's climate. Prof Peter Thorne, climatologist and lead author on that report, joins physicist and oceanographer Dr Helen Czerski and weather presenter Geoff Maskell to talk about what needs to be done to avert disaster.



WHITBY AND THE COSMOS: THE SEARCH FOR DARK MATTER WHITBY MUSEUM, WHITBY

16 FEBRUARY - 20 JULY 2019 WHITBYMUSEUM.ORG.UK

SEARCH FOR DARK MATTER

The Boulby Underground Laboratory in North Yorkshire sits a kilometre below the Earth's surface, making it the perfect place to study dark matter without interference of natural background radiation.

If you pay a visit to a new exhibition at the Whitby Museum, then you can discover more about the dark matter experiments taking place at Boulby. At the exhibition, you'll find cutting-edge devices, such as the ZEPLIN-III. This was built to detect WIMPS (weakly interactive massive particles), which are thought to constitute dark matter. There are also some older instruments on display, including those used by Captain Cook's research team to map the transit of Venus. Cook, who was a Yorkshireman, is depicted holding some of these instruments in a famous statue (pictured) that was built to commemorate his contribution to the understanding of our Universe.

CRAFT & GRAFT: MAKING SCIENCE HAPPEN

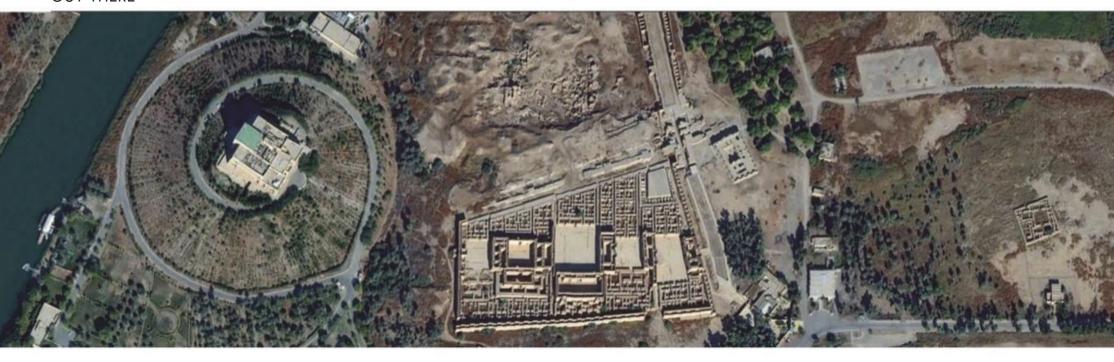
THE FRANCIS CRICK INSTITUTE, LONDON 1 MARCH - 30 NOVEMBER 2019 CRICK.AC.UK

PEEK BEHIND THE CURTAIN

Each year at the Francis Crick Institute in London, 1.5 million flies need to be fed, and billions of cancer cells have to be cared for. Craft & Graft: Making Science Happen lets us look behind the scenes to see how Europe's biggest biomedical research institute functions.

The exhibition shines a light on five specialist teams, who are opening their doors to the public for the first time. Those include teams responsible for injecting DNA into fly embryos by hand, the mechanical and electronic engineers who race against the clock to fix, adapt or invent equipment for the labs, and the specialists who prepare biological samples so tiny and delicate that they regularly use an eyelash glued to a cocktail stick as one of their tools (see right).





ORIGINS: HOW

THE EARTH

MADE US LEWIS DARTNELL OUT NOW (£18.99, BODLEY HEAD)



DISCOVER OUR ORIGINS

In his new book, astrobiologist LEWIS DARTNELL shows us how the Earth's ancient geography has influenced the development of human civilisations, and how it still affects our behaviour today

What is *Origins* about?

It's about the many ways that different features of planet Earth have directed the course of human evolution and influenced the growth and development of civilisations over thousands of years. It looks at fundamental features like plate tectonics, or atmospheric circulation patterns, showing how they've directed the course of our history and why the world is the way we find it today.

What prompted you to write the book?

I'm an astrobiologist, which is all about looking at the possibility of life on other planets, so I spend a lot of my day-to-day working life thinking about how the features of Earth have made it habitable in the most fundamental sense.

I wanted this new book to expand on that – to bridge the gap between science and history and see how they inform each other. Through *Origins* I try to weave those two back and forth through the chapters of the book, like two strands of a narrative.

You talk about plate tectonics in the book. How have they affected human development?

When you look at a map of where ancient civilisations started, a lot seem to huddle along tectonic

boundaries. Plate boundaries are dangerous places to be in one sense, because that's where earthquakes and volcanoes are concentrated, but clearly they're also providing some sort of benefit. Take Mesopotamia, the land between the Tigris and the Euphrates rivers in the Middle East. That entire region is essentially running along the tectonic trough that was created when the Arabian plate pivoted away from Africa and slammed into Eurasia, which then collected great rivers and sediment to make fertile soil. So in that particular instance there's a very clear reason why some of the earliest cities in our history grew up around that particular tectonic region, as it was a really conducive place to settle down and go through the beginnings of agriculture.

How has geography influenced current behaviour?

One modern example is the election of Donald Trump. If you look at an election map of the southeast region of the US, it's a sea of Republican red. But in that sea of red there's this very distinct crescent shape of blue, of people voting Democrat. If you look at a geological map, underneath that crescent of Democrat-voting

counties is a stratum of thick, fertile sea mud that dates back 60-70 million years. Cotton grew well in that rich fertile soil, and in the 1840s, 1850s and 1860s, slaves were used to grow and harvest cotton. More than 150 years later, the descendants of those slaves still live in that region, and their socioeconomic background means they're more likely to be voting Democrat, rather than Republican.

Is it important to be aware of how these physical formations are influencing our behaviour?

We're now turning all of this on its head with our modern industrialised civilisation. A lot of scientists are calling this current era the Anthropocene, because humanity has become the dominant force in changing our planet. We've got a lot of problems on our doorstep to do with climate change, global warming and ocean acidification, and we need to find solutions to them so we can keep living the way we've become accustomed to. I think by appreciating this deep link behind how the Earth has made us and how we're now affecting the Earth in return, you just appreciate everything around you a little bit more, and understand why we need to take extra care of the planet.

GETTY IMAGES X2, AGI HAINES



SPARE PARTS SCIENCE GALLERY LONDON 28 FEBRUARY – 12 MAY 2019 LONDON.SCIENCEGALLERY.COM

BUILD SPARE PARTS

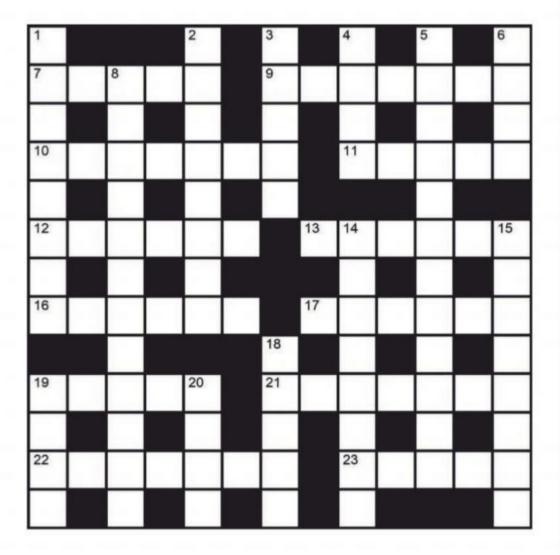
We're now able to enhance, regenerate or alter more parts of our bodies than ever before. But what are the emotional and psychological effects of living with an engineered organ or limb? These questions are being asked in *Spare Parts*, a new exhibition at the Science Gallery London.

The exhibition explores the science, ethics and technology around the repair or alteration of the human body. It discusses the experience of being ill or less able, while also looking at the human ability to recover, cultivate resilience and celebrate difference. Mixing science and art, *Spare Parts* includes thought-provoking works from visual artists, and pioneering new studies from the King's College Faculty of Life Sciences and Medicine.



BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 7 It gets boring, right after gold, say, is put back (5)
- **9** Policeman returned greeting, noticing first cetacean (7)
- 10 Cross, wiggling his tongue (7)
- 11 Article takes object to be a former tax (5)
- 12 Almost bringing up some fruit (6)
- About to sail away to coastal city (6)
- Fool not registered queen has a heart (6)
- 17 Misdemeanour on a peninsula (6)
- Sale involved carpenter's last beam (5)
- 21 Deduce negative was in conflagration (7)
- 22 Elm generated an up to date pigment (7)
- 23 Tin production around the French bay (5)

DOWN

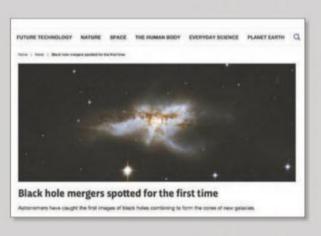
- Second worker takes risk, translating language (8)
- 2 Trickery and craft with diamonds, if included (8)
- 3 Hid a horse around part of America (5)
- 4 Sticky lump left in bed (4)
- **5** With renewed energy, almost revere a large butterfly (5,7)
- **6** Keen for operation in joint (4)
- 8 Its small cage ruined the Lyon family home (6,6)
- 14 Supplier of lift may fare badly with old lubricant (8)
- Use rate conversion to get round shipping lane (3,5)
- 18 To criticise gets one nothing but an instrument (5)
- Youngster left in the morning on bike, initially (4)
- 20 Disgusting position (4)

CARNEGIE INSTITUTE FOR SCIENCE, GETTY IMAGES

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**Please be aware the website address is case-sensitive.

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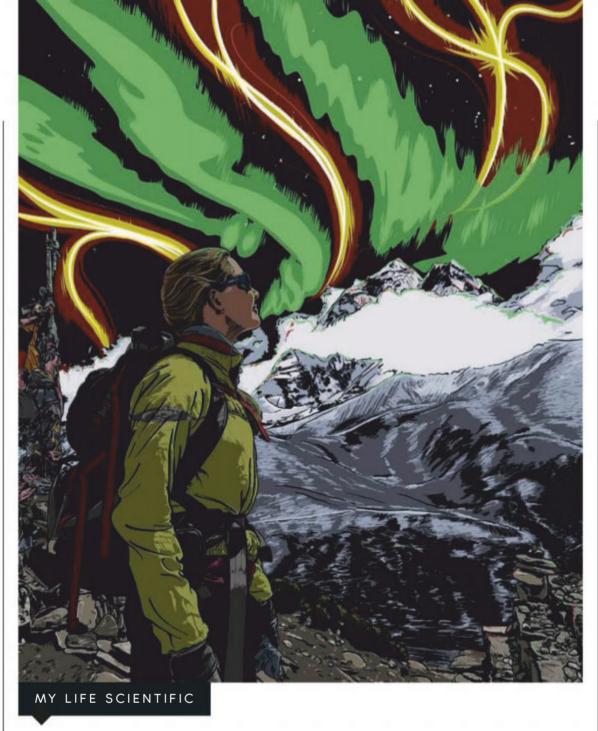
The engineering behind the biggest movers on the planet



How charismatic leaders fail their way to the top

ON SALE 6 MARCH





Dr Melanie Windridge

This month, plasma physicist **Melanie Windridge** talks to **Helen Pilcher** about her twin passions of science and exploration

Melanie's book,
Aurora: In Search
Of The Northern
Lights, is available
in paperback
now (£12.99,
William Collins).

What do you do?

I'm a physicist working with Tokamak Energy, a company that's developing fusion energy. I've just climbed Everest and am writing a book about the science behind it.

What's the link between science and exploration?

Science is an exploration. In my work, we're trying to create a clean energy source for humankind. Fusion energy is cutting edge. It's exploration. It's going places people have never been before and trying to do something that seems almost

impossible. If you think about polar exploration or climbing Everest, it's the same kind of thing.

How did you get into exploration?

I had a pivotal moment when I was at university. My housemate told me that if I transferred to a slightly different degree, I'd get to go to France and go skiing every weekend. So I did. I spent my third year in Grenoble. It made me realise there was a whole world outside of my bubble, and made me less scared of doing things that challenge me. Most importantly, it made me want to be in the mountains.

"FUSION ENERGY IS CUTTING EDGE.
IT'S EXPLORATION. IT'S GOING PLACES
PEOPLE HAVE NEVER BEEN BEFORE"

What's been your toughest adventure?

In 2015, I spent a week skiing across Svalbard in the Arctic to see the aurora – a plasma phenomenon. The temperature got down to -40°C. Everything was frozen all the time, even in the tent. You spend your whole day oscillating in and out of pain, because every time you need the dexterity of your fingers and you take your mittens off, they start to hurt within seconds.

What about Everest?

Everest is different. It's not so cold, but it's long and drawn out. The altitude wears you down. Little things like coughs and colds don't get better, and you end up climbing this incredible mountain when you should be in bed recovering. You need experience to know how to look after yourself; not so you can climb, but so you can stay alive.

Which should I visit?

I'd encourage people to go to the Arctic. It's a different kind of place. The light's different. It's magical and it's harsh. You imagine the Arctic as being this soft, snowy landscape that's cutesy and Christmassy, but it's ice and rock and wind. Then there's the aurora. I've seen them four or five times now, and it's still not enough.

What life skills have you learned?

One of the scariest things you have to do on Everest is to cross large crevasses by balancing on ladders. It taught me how to manage my fear. The mountains have also taught me patience and acceptance. When you're climbing, you can't control the weather. Sometimes you have no choice but to wait it out.

One message for our readers?

Whether it is scientific or geographical, go out and explore! •

Dr Melanie Windridge is an academic visitor in plasma physics at Imperial College London. Find out more about the science of Everest at **bit.ly/EverestIOP**

DISCOVER MORE



To listen to episodes of *The Life Scientific* with top scientists, visit **bit.ly/life_scientific**

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